

INDIAN AGRICULTURAL RESEARCH
INSTITUTE, NEW DELHI.

CARNEGIE INSTITUTION
OF
WASHINGTON

YEAR BOOK No. 28

JULY 1, 1928, TO JUNE 30, 1929

WITH ADMINISTRATIVE REPORTS THROUGH DECEMBER 13, 1929



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CONTENTS

	PAGE
Organization and Scope	IX
Articles of Incorporation	X-XII
By-Laws of the Institution	XIII-XVI
Minutes of the Thirtieth Meeting of the Board of Trustees	XVII-XIX
Report of the President of the Institution	1-69
Bibliography of Publications relating to work of Investigators, Associates, and Collaborators	70-98
Report of the Executive Committee	98-98
Aggregate Receipts and Disbursements	98
Report of Auditors and Financial Statement	99-105
Reports on Investigations and Projects:	
Department of Embryology	3-32
Department of Genetics	33-66
Geophysical Laboratory	67-83
Department of Historical Research	85-92
Department of Meridian Astrometry	93-99
Mount Wilson Observatory	101-145
Nutrition Laboratory	147-159
Division of Plant Biology	161-208
Department of Terrestrial Magnetism	209-276
Tortugas Laboratory	277-297
Other Investigations:	
Archaeology:	
Morley, Sylvanus G.	299-333
Biology:	
Bailey, I. W.	334
Castle, W. E.	334-335
Crampton, H. E.	336
Mann, Albert.	336-338
Morgan, T. H., A. H. Sturtevant, and C. B. Bridges	338-345
Sumner, F. B.	346-347
Tennent, D. H.	347
Chemistry:	
Noyes, Arthur A.	348-350
Richards, Theodore W.	351
Sherman, H. C.	351-354
Genetics:	
Babcock, E. B.	355-358
History of Science:	
Sarton, George	359
Indian Art:	
Blish, Helen	360
Mathematics:	
Dickson, L. E.	361
Meteorology:	
Bjerknes, V.	362-366
Nutrition:	
Mendel, L. B., and H. B. Vickery	367-377
Williams, R. R., and Walter H. Eddy	377-385
Palaeography:	
Lowe, E. A.	386
Palaeontology:	
Antevs, Ernst	387
Merriam, John C., and Associates	388-391
Stoyanow, A. A.	392
White, David	392-933

Other Investigations—continued:	PAGE
Philosophy:	
Heidel, W. A.....	394
Physics:	
Compton, K. T.....	395
Millikan, R. A.....	395-398
Committee on Study of Physical Features of Surface of Moon.....	398-401
Physiology:	
Russell, G. Oscar.....	402
Psychology:	
Gault, Robert H.....	403-414
Pearson, Karl, and Henry A. Ruger.....	415
Seismology:	
Advisory Committee.....	416-424
Index.....	425-439

PRESIDENT

JOHN C. MERRIAM

FORMER PRESIDENTS

*DANIEL COIT GILMAN, 1902-04

*ROBERT SIMPSON WOODWARD, 1904-20

BOARD OF TRUSTEES

ELIHU ROOT, *Chairman*

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W. W. CAMPBELL	HERBERT C. HOOVER	HENRY S. PRITCHETT
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EXECUTIVE COMMITTEE: ELIHU ROOT, *Chairman*; W. CAMERON FORBES, CASS GILBERT,
JOHN C. MERRIAM, WM. CHURCH OSBORN, WM. BARCLAY PARSONS,
STEWART PATON, HENRY S. PRITCHETT

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*ALEXANDER AGASSIZ	1904-05	*CHARLES L. HUTCHINSON	1902-24
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*JOHN S. BILLINGS	1902-13	*WILLIAM LINDSAY	1902-09
ROBERT S. BROOKINGS	1910-29	*HENRY CABOT LODGE	1914-24
*JOHN L. CADWALADER	1903-14	*SETH LOW	1902-16
*CLEVELAND H. DODGE	1903-23	*WAYNE MACVEAGH	1902-07
*WILLIAM E. DODGE	1902-03	*DARIUS O. MILLS	1902-09
*CHARLES P. FENNER	1914-24	*S. WEIR MITCHELL	1902-14
SIMON FLEXNER	1910-14	*WILLIAM W. MORROW	1902-29
*WILLIAM N. FREW	1902-15	GEORGE W. PEPPER	1914-19
*LYMAN J. GAGE	1902-12	MARTIN A. RYERSON	1908-28
*DANIEL C. GILMAN	1902-08	*JOHN C. SPOONER	1902-07
*JOHN HAY	1902-05	WILLIAM H. TAFT	1906-15
*MYRON T. HERRICK	1915-29	*CHARLES D. WALCOTT	1902-27
*ABRAM S. HEWITT	1902-03	HENRY P. WALCOTT	1910-24
*HENRY L. HIGGINSON	1902-19	*ANDREW D. WHITE	1902-16
*ETHAN A. HITCHCOCK	1902-09	*EDWARD D. WHITE	1902-03
*HENRY HITCHCOCK	1902-02	*HENRY WHITE	1913-27
*WILLIAM WIRT HOWE	1903-09	*ROBERT S. WOODWARD	1905-24
*CARROLL D. WRIGHT	1902-08		

* Deceased

Besides the names enumerated above, the following were ex-officio members of the Board of Trustees under the original charter, from the date of organization until April 28, 1904; the President of the United States, the President of the Senate, the Speaker of the House of Representatives, the Secretary of the Smithsonian Institution, the President of the National Academy of Sciences.

STAFF OF INVESTIGATORS

Department of Embryology:

Established 1914; Franklin P. Mall, Director 1914-1917.

GEORGE L. STREETER, Director
CARL G. HARTMAN
CHESTER H. HEUSER

MARGARET R. LEWIS
WARREN H. LEWIS

Department of Genetics:

Station for Experimental Evolution, opened in 1904, was combined with Eugenics Record Office in 1921 to form Department of Genetics.

CHARLES B. DAVENPORT, Director
A. F. BLAKESLEE, Assistant Director
H. H. LAUGHLIN, Assistant Director
A. G. AVERY
H. J. BANKER
A. M. BANTA
A. DOROTHY BERGNER

M. DEMEREC
A. H. ESTABROOK (resigned)
E. C. MACDOWELL
C. W. METZ
OSCAR RIDDLE
SOPHIE SATINA

Geophysical Laboratory:

Organized 1906, opened 1907.

ARTHUR L. DAY, Director
L. H. ADAMS
EUGENE T. ALLEN
N. L. BOWEN
C. N. FENNER
R. E. GIBSON
R. W. GORANSON
J. W. GREIG
J. H. HIBBEN
F. C. KRACEK
C. J. KSANDA
H. E. MERWIN

G. W. MOREY
CHARLES S. PIGGOT
EUGENE POSNJAK
H. S. ROBERTS
J. F. SCHAIERER
E. S. SHEPHERD
GEORGE TUNELL
H. S. WASHINGTON
WALTER P. WHITE
FRED E. WRIGHT
E. G. ZIES

Department of Historical Research:

Organized 1903; Andrew C. McLaughlin, Director 1903-1905, J. Franklin Jameson, Director 1905-1928.

EDMUND C. BURNETT
WALDO G. LELAND (absent on leave)

CHARLES O. PAULLIN
LEO F. STOCK

Department of Meridian Astrometry:

Established 1907; Lewis Boss, Director 1907-1912.

BENJAMIN BOSS, Director
SEBASTIAN ALBRECHT
SHERWOOD B. GRANT
HEROY JENKINS

HARRY RAYMOND
ARTHUR J. ROY
W. B. VARNUM
RALPH E. WILSON

Mount Wilson Observatory:

Established 1904; George E. Hale, Director 1904-1923.

GEORGE E. HALE, Honorary Director
WALTER S. ADAMS, Director
F. H. SEARES, Assistant Director
ALFRED H. JOY, Secretary
A. S. KING, Supt. Physical Laboratory
J. A. ANDERSON
HAROLD D. BABCOCK
THEODORE DUNHAM Jr.
FERDINAND ELLERMAN
EDWIN P. HUBBLE

MILTON L. HUMASON
PAUL W. MERRILL
SETH B. NICHOLSON
FRANCIS G. PEASE
EDISON PETTIT
R. F. SANFORD
SINCLAIR SMITH
GUSTAF STRÖMBERG
CHARLES E. ST. JOHN
A. VAN MAANEN

Nutrition Laboratory:

Organized in 1907, opened 1908.

FRANCIS G. BENEDICT, Director
T. M. CARPENTER
V. COROPATCHINSKY

E. L. FOX
E. S. MILLS (Retired)

Division of Plant Biology:

Desert Laboratory, opened in 1903, became headquarters of Department of Botanical Research in 1905. Name changed to Laboratory for Plant Physiology in 1923, and reorganized in 1928 as Division of Plant Biology, including Ecology.

H. A. SPOEHR, Chairman
JOHN BELLING
RALPH W. CHANEY
FREDERIC E. CLEMENTS
G. W. GOLDSMITH (resigned)
H. M. HALL
FRANCES L. LONG

DANIEL T. MACDOUGAL
H. W. MILNER
FORREST SHREVE
JAMES H. C. SMITH
H. H. STRAIN
GODFREY SYKES (retired)
GEORGE R. WIELAND

Department of Terrestrial Magnetism:

Organized 1904.

LOUIS A. BAUER, Director
J. A. FLEMING, Assistant Director
*J. P. AULT
G. BREIT (resigned)
G. BUILDER
O. DAHL
C. R. DUVAL
V. J. EATON
H. M. W. EDMONDS
C. C. ENNIS
H. W. FISK
S. E. FORBUSH
O. H. GISH
H. W. GRAHAM
JOHN W. GREEN
L. R. HAFSTAD

C. HUFF
H. F. JOHNSTON
P. G. LEDIG
WILFRED C. PARKINSON
J. H. PAUL
W. J. PETERS
W. J. ROONEY
W. E. SCOTT
S. L. SEATON
K. L. SHERMAN
F. M. SOULE
OSCAR W. TORRESON
M. A. TUVE
G. R. WAIT
W. F. WALLIS
F. W. WOOD

Early American History including Middle American Archaeological Research:

A. V. KIDDER, Associate
SYLVANUS G. MORLEY, Associate
EARL H. MORRIS

O. G. RICKETSON, JR.
KARL RUPPERT

Investigators at Tortugas Laboratory, Summer 1929:

L. R. BLINKS, Rockefeller Institute
C. M. BREDER JR., New York Aquarium and American Museum of Natural History
MARTIN BURKENROAD, Tulane University
PAUL S. CONGER, Carnegie Institution
CASWELL GRAVE, Washington University
DWIGHT L. HOPKINS, Duke University
W. H. LONGLEY, Goucher College
OLIVER H. MCCOY, Johns Hopkins University
H. M. MILLER JR., Washington University
D. H. TENNENT, Bryn Mawr College
WILLIAM WARTMANN, University of Pennsylvania Medical School
SHIGEO YAMANOUCHI, University of Tokyo

* Deceased

Fellow of the Institution:

ALEXANDER POGO, History of Science

Other Investigators:

OLIVER P. HAY, Associate in Palæontology (retired)

W. A. HEIDEL, Research Associate in Philosophy

ELIAS A. LOWE, Associate in Palæography

ALBERT MANN, Research Associate in Biology

GEORGE SARTON, Associate in History of Science

HARRY O. WOOD, Research Associate in Seismology

Additional Research Associates connected with other Institutions:

ERNST ANTEVS (American Museum of Natural History), Palæontology

I. W. BAILEY (Bussey Institution), Biology

E. B. BABCOCK (University of California), Genetics

V. BJERKNES (University of Oslo, Norway), Meteorology

HELEN BLISH (University of Nebraska), Indian Art

J. P. BUWALDA (California Institute of Technology), Palæontology

W. E. CASTLE (Harvard University), Biology

H. L. CLARK (Harvard University), Biology

K. T. COMPTON (Princeton University), Spectroscopy

H. E. CRAMPTON (Columbia University), Biology

L. E. DICKSON (University of Chicago), Mathematics

A. E. DOUGLASS (University of Arizona), Ecology

WALTER EDDY (Columbia University), Physiological Chemistry

ROBERT H. GAULT (Northwestern University), Psychology

J. H. JEANS (Royal Society of London), Astronomy

REMINGTON KELLOGG (U. S. National Museum), Palæontology

A. E. KENNELLY (Harvard University), Terrestrial Magnetism

D. N. LEHMER (University of California), Mathematics

L. B. MENDEL (Yale University), Physiological Chemistry

A. A. MICHELSON (University of Chicago), Astronomy

R. A. MILLIKAN (California Institute of Technology), Physics

T. H. MORGAN (California Institute of Technology), Biology

ROBERT K. NABOURS (Kansas State Agricultural College), Genetics

HARVEY E. NEWTON (Princeton University), Biology

A. A. NOYES (California Institute of Technology), Chemistry

GREENLEAF W. PICKARD, Terrestrial Magnetism

HENRY A. RUGER (Columbia University), Psychology

G. OSCAR RUSSELL (Ohio State University), Physiology

HENRY N. RUSSELL (Princeton University), Astronomy

H. C. SHERMAN (Columbia University), Chemistry

CHESTER STOCK (California Institute of Technology), Palæontology

A. A. STOYANOW (University of Arizona), Palæontology

F. B. SUMNER (Scripps Institution of Oceanography), Biology

H. U. SVERDRUP (Geophysical Institute, Bergen, Norway), Terrestrial Magnetism

D. H. TENNENT (Bryn Mawr College), Biology

H. B. VICKERY (Connecticut Agri. Exper. Station), Physiological Chemistry

J. E. WEAVER (University of Nebraska), Ecology

LEWIS H. WEED (Johns Hopkins Medical School), Anatomy

DAVID WHITE (National Academy of Sciences), Palæontology

R. R. WILLIAMS (Bell Telephone Laboratories), Physiological Chemistry

BAILEY WILLIS (Stanford University), Seismology

CLARK WISSLER (American Museum of Natural History), Archæology

ORGANIZATION, PLAN AND SCOPE

The Carnegie Institution of Washington was founded by Mr. Andrew Carnegie, January 28, 1902, when he gave to a board of trustees an endowment of registered bonds of the par value of ten million dollars. To this fund an addition of two million dollars was made by Mr. Carnegie on December 10, 1907, and a further addition of ten million dollars was made by him January 19, 1911; so that the present endowment of the Institution has a par value of twenty-two million dollars. The Institution was originally organized under the laws of the District of Columbia and incorporated as the *Carnegie Institution*, articles of incorporation having been executed on January 4, 1902. The Institution was reincorporated, however, by an act of the Congress of the United States, approved April 28, 1904, under the title of *The Carnegie Institution of Washington*. (See existing Articles of Incorporation on the following pages.)

Organization under the new Articles of Incorporation was effected May 18, 1904, and the Institution was placed under the control of a board of twenty-four trustees, all of whom had been members of the original corporation. The trustees meet annually in December to consider the affairs of the Institution in general, the progress of work already undertaken, the initiation of new projects, and to make the necessary appropriations for the ensuing year. During the intervals between the meetings of the trustees the affairs of the Institution are conducted by an Executive Committee chosen by and from the Board of Trustees and acting through the President of the Institution as chief executive officer.

The Articles of Incorporation of the Institution declare in general "that the objects of the corporation shall be to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind." Three principal agencies to forward these objects have been developed. The first of these involves the establishment of departments of research within the Institution itself, to attack larger problems requiring the collaboration of several investigators, special equipment, and continuous effort. The second provides means whereby individuals may undertake and carry to completion investigations not less important but requiring less collaboration and less special equipment. The third agency, namely, a division devoted to editing and printing books, aims to provide adequate publication of the results of research coming from the first two agencies and to a limited extent also for worthy works not likely to be published under other auspices.

ARTICLES OF INCORPORATION

PUBLIC No. 260.—An Act To incorporate the Carnegie Institution of Washington

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the persons following, being persons who are now trustees of the Carnegie Institution, namely, Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, Samuel P. Langley, William Lindsay, Seth Low, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, Ethan A. Hitchcock, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D. Wright, their associates and successors, duly chosen, are hereby incorporated and declared to be a body corporate by the name of the Carnegie Institution of Washington and by that name shall be known and have perpetual succession, with the powers, limitations, and restrictions herein contained.

SEC. 2. That the objects of the corporation shall be to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind; and in particular—

(a) To conduct, endow, and assist investigation in any department of science, literature, or art, and to this end to cooperate with governments, universities, colleges, technical schools, learned societies, and individuals.

(b) To appoint committees of experts to direct special lines of research.

(c) To publish and distribute documents.

(d) To conduct lectures, hold meetings and acquire and maintain a library.

(e) To purchase such property, real or personal, and construct such building or buildings as may be necessary to carry on the work of the corporation.

(f) In general, to do and perform all things necessary to promote the objects of the institution, with full power, however, to the trustees hereinafter appointed and their successors from time to time to modify the conditions and regulations under which the work shall be carried on, so as to secure the application of the funds in the manner best adapted to the conditions of the time, provided that the objects of the corporation shall at all times be among the foregoing or kindred thereto.

SEC. 3. That the direction and management of the affairs of the corporation and the control and disposal of its property and funds shall be vested in a board of trustees, twenty-two in number, to be composed of the following individuals: Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, Samuel P. Langley, William Lindsay, Seth Low, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, Ethan A. Hitchcock, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D.

ARTICLES OF INCORPORATION

Wright, who shall constitute the first board of trustees. The board of trustees shall have power from time to time to increase its membership to not more than twenty-seven members. Vacancies occasioned by death, resignation, or otherwise shall be filled by the remaining trustees in such manner as the by-laws shall prescribe; and the persons so elected shall thereupon become trustees and also members of the said corporation. The principal place of business of the said corporation shall be the city of Washington, in the District of Columbia.

SEC. 4. That such board of trustees shall be entitled to take, hold, and administer the securities, funds, and property so transferred by said Andrew Carnegie to the trustees of the Carnegie Institution and such other funds or property as may at any time be given, devised, or bequeathed to them, or to such corporation, for the purposes of the trust; and with full power from time to time to adopt a common seal, to appoint such officers, members of the board of trustees or otherwise, and such employees as may be deemed necessary in carrying on the business of the corporation, at such salaries or with such remuneration as they may deem proper; and with full power to adopt by-laws from time to time and such rules or regulations as may be necessary to secure the safe and convenient transaction of the business of the corporation; and with full power and discretion to deal with and expend the income of the corporation in such manner as in their judgment will best promote the objects herein set forth and in general to have and use all powers and authority necessary to promote such objects and carry out the purposes of the donor. The said trustees shall have further power from time to time to hold as investments the securities hereinabove referred to so transferred by Andrew Carnegie, and any property which has been or may be transferred to them or such corporation by Andrew Carnegie or by any other person, persons, or corporation, and to invest any sums or amounts from time to time in such securities and in such form and manner as are permitted to trustees or to charitable or literary corporations for investment, according to the laws of the States of New York, Pennsylvania, or Massachusetts, or in such securities as are authorized for investment by the said deed of trust so executed by Andrew Carnegie, or by any deed of gift or last will and testament to be hereafter made or executed.

SEC. 5. That the said corporation may take and hold any additional donations, grants, devises, or bequests which may be made in further support of the purposes of the said corporation, and may include in the expenses thereof the personal expenses which the trustees may incur in attending meetings or otherwise in carrying out the business of the trust, but the services of the trustees as such shall be gratuitous.

SEC. 6. That as soon as may be possible after the passage of this Act a meeting of the trustees hereinbefore named shall be called by Daniel C. Gilman, John S. Billings, Charles D. Walcott, S. Weir Mitchell, John Hay, Elihu Root, and Carroll D. Wright, or any four of them, at the city of Washington, in the District of Columbia, by notice served in person or by mail addressed to each trustee at his place of residence; and the said trustees, or a majority thereof, being assembled, shall organize and proceed to adopt by-laws, to elect officers and appoint committees, and generally to organize the said corporation; and said trustees herein named, on behalf of the corpora-

ARTICLES OF INCORPORATION

tion hereby incorporated, shall thereupon receive, take over, and enter into possession, custody, and management of all property, real or personal, of the corporation heretofore known as the Carnegie Institution, incorporated, as hereinbefore set forth under "An Act to establish a Code of Law for the District of Columbia, January fourth, nineteen hundred and two," and to all its rights, contracts, claims, and property of any kind or nature; and the several officers of such corporation, or any other person having charge of any of the securities, funds, real or personal, books or property thereof, shall, on demand, deliver the same to the said trustees appointed by this Act or to the persons appointed by them to receive the same; and the trustees of the existing corporation and the trustees herein named shall and may take such other steps as shall be necessary to carry out the purposes of this Act.

SEC. 7. That the rights of the creditors of the said existing corporation known as the Carnegie Institution shall not in any manner be impaired by the passage of this Act, or the transfer of the property hereinbefore mentioned, nor shall any liability or obligation for the payment of any sums due or to become due, or any claim or demand, in any manner or for any cause existing against the said existing corporation, be released or impaired; but such corporation hereby incorporated is declared to succeed to the obligations and liabilities and to be held liable to pay and discharge all of the debts, liabilities, and contracts of the said corporation so existing to the same effect as if such new corporation had itself incurred the obligation or liability to pay such debt or damages, and no such action or proceeding before any court or tribunal shall be deemed to have abated or been discontinued by reason of the passage of this Act.

SEC. 8. That Congress may from time to time alter, repeal, or modify this Act of incorporation, but no contract or individual right made or acquired shall thereby be divested or impaired.

SEC. 9. That this Act shall take effect immediately.

Approved, April 28, 1904.

BY-LAWS OF THE INSTITUTION

Adopted December 13, 1904. Amended December 13, 1910, and December 13, 1912.

ARTICLE I.

THE TRUSTEES.

1. The Board of Trustees shall consist of twenty-four members, with power to increase its membership to not more than twenty-seven members. The Trustees shall hold office continuously and not for a stated term.

2. In case any Trustee shall fail to attend three successive annual meetings of the Board he shall thereupon cease to be a Trustee.

3. No Trustee shall receive any compensation for his services as such.

4. All vacancies in the Board of Trustees shall be filled by the Trustees by ballot. Sixty days prior to an annual or a special meeting of the Board, the President shall notify the Trustees by mail of the vacancies to be filled and each Trustee may submit nominations for such vacancies. A list of the persons so nominated, with the names of the proposers, shall be mailed to the Trustees thirty days before the meeting, and no other nominations shall be received at the meeting except with the unanimous consent of the Trustees present. Vacancies shall be filled from the persons thus nominated, but no person shall be declared elected unless he receives the votes of two-thirds of the Trustees present.

ARTICLE II.

MEETINGS.

1. The annual meeting of the Board of Trustees shall be held in the City of Washington, in the District of Columbia, on the first Friday following the second Thursday of December in each year.

2. Special meetings of the Board may be called by the Executive Committee by notice served personally upon, or mailed to the usual address of, each Trustee twenty days prior to the meeting.

3. Special meetings shall, moreover, be called in the same manner by the Chairman upon the written request of seven members of the Board.

ARTICLE III.

OFFICERS OF THE BOARD.

1. The officers of the Board shall be a Chairman of the Board, a Vice-Chairman, and a Secretary, who shall be elected by the Trustees, from the members of the Board, by ballot to serve for a term of three years. All vacancies shall be filled by the Board for the unexpired term; provided, however, that the Executive Committee shall have power to fill a vacancy in the office of Secretary to serve until the next meeting of the Board of Trustees.

BY-LAWS OF THE INSTITUTION

2. The Chairman shall preside at all meetings and shall have the usual powers of a presiding officer.

3. The Vice-Chairman, in the absence or disability of the Chairman, shall perform his duties.

4. The Secretary shall issue notices of meetings of the Board, record its transactions, and conduct that part of the correspondence relating to the Board and to his duties. He shall execute all deeds, contracts or other instruments on behalf of the corporation, when duly authorized.

ARTICLE IV.

EXECUTIVE ADMINISTRATION.

The President.

1. There shall be a President who shall be elected by ballot by, and hold office during the pleasure of, the Board, who shall be the chief executive officer of the Institution. The President, subject to the control of the Board and the Executive Committee, shall have general charge of all matters of administration and supervision of all arrangements for research and other work undertaken by the Institution or with its funds. He shall devote his entire time to the affairs of the Institution. He shall prepare and submit to the Board of Trustees and to the Executive Committee plans and suggestions for the work of the Institution, shall conduct its general correspondence and the correspondence with applicants for grants and with the special advisers of the Committee, and shall present his recommendations in each case to the Executive Committee for decision. All proposals and requests for grants shall be referred to the President for consideration and report. He shall have power to remove and appoint subordinate employees and shall be *ex officio* a member of the Executive Committee.

2. He shall be the legal custodian of the seal and of all property of the Institution whose custody is not otherwise provided for. He shall affix the seal of the corporation whenever authorized to do so by the Board of Trustees or by the Executive Committee or by the Finance Committee. He shall be responsible for the expenditure and disbursement of all funds of the Institution in accordance with the directions of the Board and of the Executive Committee, and shall keep accurate accounts of all receipts and disbursements. He shall submit to the Board of Trustees at least one month before its annual meeting in December a written report of the operations and business of the Institution for the preceding fiscal year with his recommendations for work and appropriations for the succeeding fiscal year, which shall be forthwith transmitted to each member of the Board.

3. He shall attend all meetings of the Board of Trustees.

ARTICLE V.

COMMITTEES.

1. There shall be the following standing Committees, viz., an Executive Committee, a Finance Committee, and an Auditing Committee.

BY-LAWS OF THE INSTITUTION

2. The Executive Committee shall consist of the Chairman and Secretary of the Board of Trustees and the President of the Institution *ex officio* and, in addition, five trustees to be elected by the Board by ballot for a term of three years, who shall be eligible for re-election. Any member elected to fill a vacancy shall serve for the remainder of his predecessor's term: Provided, however, that of the Executive Committee first elected after the adoption of these by-laws two shall serve for one year, two shall serve for two years, and one shall serve for three years; and such Committee shall determine their respective terms by lot.

3. The Executive Committee shall, when the Board is not in session and has not given specific directions, have general control of the administration of the affairs of the corporation and general supervision of all arrangements for administration, research, and other matters undertaken or promoted by the Institution; shall appoint advisory committees for specific duties; shall determine all payments and salaries; and keep a written record of all transactions and expenditures and submit the same to the Board of Trustees at each meeting, and it shall also submit to the Board of Trustees a printed or typewritten report of each of its meetings, and at the annual meeting shall submit to the Board a report for publication.

4. The Executive Committee shall have general charge and control of all appropriations made by the Board.

5. The Finance Committee shall consist of three members to be elected by the Board of Trustees by ballot for a term of three years.

6. The Finance Committee shall have custody of the securities of the corporation and general charge of its investments and invested funds, and shall care for and dispose of the same subject to the directions of the Board of Trustees. It shall consider and recommend to the Board from time to time such measures as in its opinion will promote the financial interests of the Institution, and shall make a report at each meeting of the Board.

7. The Auditing Committee shall consist of three members to be elected by the Board of Trustees by ballot for a term of three years.

8. The Auditing Committee shall, before each annual meeting of the Board of Trustees, examine the accounts of business transacted under the Finance Committee and the Executive Committee. They may avail themselves at will of the services and examination of the Auditor appointed by the Board of Trustees. They shall report to the Board upon the collection of moneys to which the Institution is entitled, upon the investment and reinvestment of principal, upon the conformity of expenditures to appropriations, and upon the system of bookkeeping, the sufficiency of the accounts, and the safety and economy of the business methods and safeguards employed.

9. All vacancies occurring in the Executive Committee and the Finance Committee shall be filled by the Trustees at the next regular meeting. In case of vacancy in the Finance Committee or the Auditing Committee, upon request of the remaining members of such committee, the Executive Committee may fill such vacancy by appointment until the next meeting of the Board of Trustees.

10. The terms of all officers and of all members of committees shall continue until their successors are elected or appointed.

BY-LAWS OF THE INSTITUTION

ARTICLE VI.

FINANCIAL ADMINISTRATION.

1. No expenditure shall be authorized or made except in pursuance of a previous appropriation by the Board of Trustees.

2. The fiscal year of the Institution shall commence on the first day of November in each year.

3. The Executive Committee, at least one month prior to the annual meeting in each year, shall cause the accounts of the Institution to be audited by a skilled accountant, to be appointed by the Board of Trustees, and shall submit to the annual meeting of the Board a full statement of the finances and work of the Institution and a detailed estimate of the expenditures for the succeeding year.

4. The Board of Trustees, at the annual meeting in each year, shall make general appropriations for the ensuing fiscal year; but nothing contained herein shall prevent the Board of Trustees from making special appropriations at any meeting.

5. The securities of the Institution and evidences of property, and funds invested and to be invested, shall be deposited in such safe depository or in the custody of such trust company and under such safeguards as the Trustees and Finance Committee shall designate; and the income available for expenditure of the Institution shall be deposited in such banks or depositories as may from time to time be designated by the Executive Committee.

6. Any trust company entrusted with the custody of securities by the Finance Committee may, by resolution of the Board of Trustees, be made Fiscal Agent of the Institution, upon an agreed compensation, for the transaction of the business coming within the authority of the Finance Committee.

ARTICLE VII.

AMENDMENT OF BY-LAWS.

1. These by-laws may be amended at any annual or special meeting of the Board of Trustees by a two-thirds vote of the members present, provided written notice of the proposed amendment shall have been served personally upon, or mailed to the usual address of, each member of the Board twenty days prior to the meeting.

**MINUTES OF THE THIRTIETH MEETING
OF THE BOARD OF TRUSTEES**

ABSTRACT OF MINUTES OF THE THIRTIETH MEETING OF BOARD OF TRUSTEES

The meeting was held in Washington in the Board Room of the Administration Building on Friday, December 13, 1929. It was called to order at 10 a. m. by the Chariman of the Board, Mr. Root.

Upon roll-call the following Trustees responded: John J. Carty, Frederic A. Delano, Homer L. Ferguson, W. Cameron Forbes, Cass Gilbert, Frederick H. Gillett, James Parmelee, Wm. Barclay Parsons, Stewart Paton, Henry S. Pritchett, Elihu Root, William Benson Storey, William H. Welch, and George W. Wickersham. The President of the Institution, John C. Merriam, was also present.

The minutes of the twenty-ninth meeting were approved as printed and submitted to the members of the Board.

Reports of the President, the Executive Committee, the Auditor, the Finance Committee, the Auditing Committee, and of Directors of Departments and Research Associates of the Institution were presented and considered.

The following appropriations for the year 1930 were authorized:

Pension Fund	\$ 50,000
Administration	68,650
Publication (including Division of Publications)	97,010
Departments and Divisions of Research	1,221,309
Minor Grants	148,000
General Contingent Fund	81,500
Special Emergency Reserve Fund	50,000

1,716,469

The resignation of Robert S. Brookings as a member of the Board of Trustees was accepted with regret.

Balloting for new Trustees to fill vacancies caused by death of Myron T. Herrick and of William W. Morrow and by resignation of Robert S. Brookings and of Martin A. Ryerson resulted in election of the following members: William W. Campbell, of California; John J. Pershing, of District of Columbia; Julius Rosenwald, of Illinois; and William S. Thayer, of Maryland.

Cass Gilbert and Wm. Church Osborn were elected members of the Executive Committee for a period of three years, to succeed John J. Carty and George W. Wickersham, whose terms of office expired with this meeting.

Mr. Parmelee was elected Chairman of the Auditing Committee, to succeed Mr. Brookings, and Mr. Delano was elected a member of this Committee, to fill the vacancy created by Mr. Brookings' resignation, for the unexpired term ending in 1930.

The meeting adjourned at 12.30 p. m.

REPORT OF THE PRESIDENT

OF THE

CARNEGIE INSTITUTION OF WASHINGTON

In conformity with Article IV, section 2, of the By-Laws of the Carnegie Institution of Washington, the President has the honor to submit the following report on the work of the Institution for the fiscal year ending October 31, 1929, together with provisional recommendation of appropriations for the year beginning January 1, 1930.

Judge William W. Morrow, senior member of the Ninth District Court of Appeals of the United States, died in San Francisco, July 24, 1929, at the age of eighty-six. He was a representative from California in the Forty-ninth to Fifty-first Congresses, was widely connected with State and National affairs, and served also on international claims commissions.

Named by Mr. Carnegie in 1902 as a member of the original Board of Trustees, Judge Morrow participated in organization and establishment of the Carnegie Institution of Washington. He was a most sympathetic and able supporter of the Institution during the period of formulation of its plans. A regular attendant at annual meetings, until illness prevented the journey across the continent, he took an active part in deliberations of the Board. His deep interest in the affairs of the Institution led to most valuable services in connection with inauguration of research activities and especially those organized and maintained on the Pacific Coast.

CARNEGIE INSTITUTION OF WASHINGTON

Through the death of Myron T. Herrick on March 21, 1929, the Institution lost a staunch supporter and vigorous exponent of the practical value of development and extension of research. Mr. Herrick was elected to the Board of Trustees in 1915. He died in Paris at his post as Ambassador of the United States to France. Throughout his activities during the period of the Great War and while Ambassador to France, he continued his contact with the Institution. Although able to attend but a few meetings, he rendered extremely valuable service to the cause of research through maintenance of important national and international contacts. Mr. Herrick was particularly interested in spread of knowledge regarding results of research work of the Institution, and was a hearty supporter of the program which is being followed in this connection.

Through the death of Thomas B. Osborne on January 29, 1929, the Institution loses one of its most distinguished associates in research. Dr. Osborne was connected with work of the Institution from May 1902 until his retirement from active investigation in July 1928. He was a pioneer in the development of our knowledge of the chemistry of the cell, and the nature and nutritive properties of vegetable proteins.

The thoroughness with which Dr. Osborne and his associates carried on their investigations brought results of exceptional scientific value. His accomplishments greatly advanced the scope and improved the methods of biochemistry and laid foundations for the important work now being continued by Dr. Lafayette Mendel and Dr. Hubert Bradford Vickery.

It is interesting to note that the studies through which Dr. Osborne and his colleagues have so ably advanced physiological chemistry have now direct relation to the biochemical investigations included in the program of the newly organized Division of Plant Biology.

Two studies carried out at Mount Wilson Observatory during the past year illustrate in a striking way the range of modern astrophysical research. The work of Hubble, Humason, and Pease on the apparent velocities of very distant nebulae has significant application to questions concerning the nature of the universe. In another direction laboratory observations of Babcock and King have led to extremely important discoveries relating to variations in the nature of the molecular form of occurrence in two of the most fundamental chemical elements, namely, oxygen and carbon. The first of these contributions may furnish a method for deriving distances of extremely remote nebulae; the other as a contribution to our understanding of the states of matter is of the first order of importance in both physics and chemistry.

As part of the program of Mount Wilson Observatory for investigation of the Sun, Dr. Adams has planned a comprehensive study of the absolute intensities of all observable lines of the solar spectrum. Plans have been made to inaugurate this work with the addition of special equipment and special service. It involves problems representing a logical development of work of the Observatory, and rests upon recently completed studies in the course of regular investigations by the staff. The contributions from this

program of research will be of basic importance in much of the astrophysical work of the Observatory, as in related fields of research in physics and chemistry.

In the past year the new interferometer, with a range of fifty feet, has been brought practically to the stage of installation. This will give an instrument with greatly increased range beyond the twenty-foot interferometer with which the classic measurements of Betelgeuse, Antares, and other stars have been made. With installation of this new equipment a widely extended field of observation will be opened for the lines of work which have characterized recent researches of Michelson and Pease on the dimensions of the stars.

In the course of the past year a fundamental study expressing one of the most interesting phases of work of the Geophysical Laboratory has been initiated through the spectroscopic investigation of elements present in flames issuing from a living volcano. This research presents in an interesting form the possibility of analysis of materials coming from the inner earth. It was made possible by cooperation of the Geophysical Laboratory with Mount Wilson Observatory. The equipment for spectroscopic study was prepared by Mr. Harold D. Babcock, of the Observatory, and was loaned to the Geophysical Laboratory for this special purpose when favorable opportunity offered for carrying out the plan. Dr. E. G. Zies, who had just completed a comprehensive study of the fumaroles of the Valley of Ten Thousand Smokes, conducted the investigation on Mount Raoeng in eastern Java.

Another contribution of the Geophysical Laboratory of exceptional interest in study of the nature and structure

of the Earth is represented by the cooperation of the Geophysical Laboratory with Dr. Vening Meinesz, of Holland, and the Department of the Navy. Through the cruise of the Submarine S-21 over selected areas in the Gulf of Mexico, the Caribbean Sea, and over portions of the South Atlantic, contribution was made of observations over the sea, which taken with information obtained over the land areas, furnishes an extremely important body of data for interpretation of the composition, structure, and incidentally of the history of crustal movements in the outer region of the Earth.

During the past year important advances have also been made in development of investigations in atomic physics conducted by the Department of Terrestrial Magnetism. These researches are planned with a view to interpretation of certain aspects of atomic structure which concern the basic physical problem of magnetism of the Earth. The theoretical studies have proceeded to such a stage that emphasis is now being placed primarily upon related experiments involving utilization of high voltages in the investigation of atomic structure. Noteworthy progress has been made in this experimental work.

As a major research operation of the Institution during the past year the progress of the ship *Carnegie* in conduct of its broad program in research on terrestrial magnetism and related problems in oceanography is of exceptional interest. Since its departure from Washington in May 1928, the vessel has sailed through the northern half of the Atlantic Ocean, the Caribbean Sea, the Panama Canal, the southeastern, central and northern portions of the Pacific, and

**Progress of
the Ship
"Carnegie"**

has touched such points as Easter Island, Peru, Tahiti, Guam, Samoa, and Japan, arriving at San Francisco in July for thorough reconditioning before entering upon the longer stretch of its three-year cruise. During this time it covered approximately 42,416 statute miles, making a total of 291,000 statute miles travelled in conduct of this work since its launching in 1909.

The results of research in all subjects have more than justified the exceptional care given in planning the program and equipment of the ship. The apparatus available represents a wider range of opportunity in the field of observation and experiment than on any previous cruise. Cooperation of many agencies in equipping the vessel has made possible much that relates to problems which have been out of range on earlier voyages. Equipment now in use makes possible additional observational work covering phases of study of the ocean and of the Earth having close relation to the basic problem of magnetism of the Earth. Such new opportunities are offered through a group of instruments with which frequent record is made of the depths of the sea over which the ship travels. Among such is the new Vening Meinesz type of gravity apparatus, giving for the first time on a surface vessel, opportunity for almost continuous observation of gravity or pull of the Earth in the course of a voyage.

It is a pleasure to note that the sonic depth-finder, serving as the basis of observations on depths and the contour of the sea floor, was made available by the Department of the Navy, while the new gravity apparatus has been installed through courtesy of the Government of Holland with cooperation of Denmark.

Opportunity for expansion of the research program in the Department of Embryology made possible by the generous extension of laboratory facilities placed at our disposal by Johns Hopkins University has occurred at the same time with marked advance in research contributions centering in this group. Outstanding in this field is the work of Dr. Lewis and Dr. Gregory in obtaining an excellent record of movement in the developing mammalian egg. Just as the egg is too small to be studied by the naked eye, but has furnished enormously increased information under the magnification of the microscope, so the movement of the elements of the cell, which are too slow to be seen under ordinary visual observation, contribute data of great importance when seen through the medium of a cinematographic record. The results of the Lewis-Gregory work include many unsuspected phenomena, and throw light on the whole field of cell mechanism and development.

In other directions the results of correlated investigations or cooperative studies have made important contribution. The work of the embryological laboratory has fitted itself closely to researches in mammalian genetics as illustrated in the investigations of Dr. E. C. MacDowell, presenting an unusually clear picture of development and the factors involved in its control.

In similar manner the cooperative research of Dr. Benedict and Dr. Riddle on the relation of the thyroid to metabolism has continued to furnish an exceptional view of the relation between development as initiating through the basic elements of heredity and the influences arising from the glands of internal secretion.

CARNEGIE INSTITUTION OF WASHINGTON

Realization of the program for development in plant biology, as outlined in previous reports, was attained in the past summer through initiation of research at the new laboratory designed to serve as headquarters for this Division. Through courtesy of Stanford University the land necessary for buildings and for experimental work has been made available on the University campus. A new central laboratory has been constructed. Accessory buildings, including preparation house and glass house, have also been completed. The new structures will be used for biochemical investigation, experimental taxonomy, and cytological work. The laboratory with associated buildings and gardens offers unusual opportunity for cooperative experimental studies on various basic problems for which equipment has heretofore been inadequate.

The new laboratory was dedicated on August 27, 1929, at a meeting of friends of the Institution concerned with researches on biological problems.

The plan of the laboratory and of the Division as it has gradually developed was the subject of consideration at the dedication ceremony. The following quotation from the remarks of Dr. H. A. Spoehr, Chairman of the Division of Plant Biology, expresses with exceptional clearness the general purposes of the Division and of the laboratory:

The biologist is primarily interested in the forces of organic nature. Manifesting these forces are the multitudinous forms of plants and animals. These are the biologist's instruments, for they alone exhibit the phenomena which are the center of his interest. It is the initiation, correlation, and succession of the changes manifested by his instruments which he is endeavoring to understand. It is our aim to approach the problem of interpreting the manifestation of life

REPORT OF THE PRESIDENT, 1930

forces from various angles. The behavior of plants under natural and controlled conditions, their detailed description and orderly arrangement, their physical components, their chemical composition and the physical and chemical forces involved in their functioning all contribute, when correlated, to the same fundamental problem. The biologist is not unmindful of the fact that his conceptions of life processes are limited and that he is still using largely empirical methods. The discovery of the mechanism in any of the complex of functions of a living organism, even when described in terms of physics and chemistry is not the real base of the problem, no more than the swing of a galvanometer reveals the nature of electricity. Yet it must ultimately contribute to its solution in the same manner that the highly technical and involved experiments of the physical sciences have contributed to an understanding of the nature of electricity.

Obviously not every phase of plant science can be intensively and adequately pursued within a single organization. It is our aim to concentrate upon a few problems of fundamental significance and, with the careful recasting of research programs to correlate aims and unify effort. On this basis the work of the Division is to be conducted in relatively small and elastic units, the particular needs of the investigations determining the organization of personnel and equipment.

Development of the year's program of researches centering upon the studies in Middle American archæology has furnished an especially significant illustration of correlated

**Correlated
Studies in
History and the
Natural Sciences** researches, toward which the several aspects of investigation make notable contribution. The program of studies as outlined for future of work in this area has involved cooperation of such agencies as would be required to give not merely the history of culture in the Middle American region, but to obtain with such data an understanding of relationships between the sequence of events in the Maya area and the history of cultural development in America. The program

involves intensive studies of Maya archæology, initiating at both the later and earlier ends of the known historical series. The exceptionally interesting work at Chichen Itzá, in Yucatan, as illustrated by study of the Temple of the Warriors, is based upon investigations at the later end of Maya history. At the earlier end of the sequence, investigations by Oliver G. Ricketson Jr. have been conducted at the site of Uaxactun, in Guatemala, the earliest dated Maya city. A first essential in conduct of the investigation has involved the securing of a complete story from the date of Uaxactun to that of the later buildings at Chichen Itzá. At the same time it has been clear that relation of the later stages of Maya history to present day development of the Maya people is essential, and that at the other end of the sequence it is equally important to understand the relationship between early Maya culture and those older stages represented in Middle America and southwestern United States.

For study of the relation of Maya history to the present-day culture stage, it is essential to bring into cooperation a wide variety of special investigations bearing upon cultural-economic-social problems. At the other end of the series, the connection between Maya culture and that of the more ancient, and perhaps more widely extended, stages of human development in America requires examination of the whole cultural history of this continent, and an intensive study of the materials which might furnish connection between the story of the Uaxactun region and the history of the southern part of the North American continent.

After overcoming great obstacles in conduct of the excavations at the site of the city of Uaxactun, the work of Mr. Oliver G. Ricketson has resulted during the past season in the uncovering of a spectacular series of remains extending the human history of this region into very early periods, and giving invaluable material for determining the origin and early affiliations of the Maya culture.

Removal of the almost formless exterior mass of the outstanding structure at Uaxactun revealed a temple of exceptional interest and beauty, this being the oldest known structure of the Maya region. Excavation beneath this building exposed seven structural levels with which were associated a considerable group of small objects and fragments of pottery. Through the medium of this series of excavations the range of relationship of the Maya culture has extended itself over a reach of time such as it had scarcely been hoped to bring into touch with Maya history in the immediate future.

The discoveries at Uaxactun have exceptional interest in the light of significant researches which have been carried out in Middle Mexico by the Mexican Government and by various institutions from Mexico and other countries. These studies in turn must be considered in the light of the investigations of very early cultural stages of southwestern United States, such as are being conducted by Mr. Morris and Dr. Kidder in association with other institutions. The rapidity with which developments in interpretation of this historical sequence have proceeded could not have been predicted, but it has been made

possible through the careful planning of these various groups of investigations in relation to each other.

As has been indicated by the rapidity in growth of information bearing upon the broader problem of Maya history, the value of discoveries, while resting upon specific observations, depends in considerable measure upon ability to see the field as a whole, and to place accurately in the perspective of such a view the new items of information as they appear.

The plan for investigation of problems in Maya history does not concern itself solely with archæological data. It has from the beginning been formulated as an attempt to see the history of this people in relation to their environment, including natural features of the region and contacts with other cultures. The area in general presents many obstacles in the way of geographical, geological, and biological investigations, since it is largely uncharted as to details of the various subjects, and much of it can be penetrated for scientific study only with difficulty.

It was therefore extremely important to members of the staff of the Institution to have opened an opportunity to view a considerable part of the region by means of an air reconnaissance proposed and carried out by Colonel C. A. Lindbergh, through the courtesy and cooperation of the Pan-American Airways, Inc. Although the examination was possible only at a time of the year when the difficulties of seeing are relatively large, the results of the voyages by Colonel Lindbergh, Dr. Kidder, and Mr. Ricketson have given an extremely valuable view of especially important parts of the area. This work serves as a guide of large value, not only with reference to location of

little known or unknown ruins, but with relation to opportunity offered for interpretation of the character of the country as illustrated in its topography, distribution of water supply, character of the vegetation, and the possibility of contrasting various types of environment such as is offered within the brief period of an airplane flight.

In the report of the President in 1921 attention was called to the opportunity of the Institution for aiding in the advancement of fundamental research through the use of its organization "as an initiating mechanism." Illustration was given of two fields in which informal committees might do important work in examination of critical subjects.

The regions for study specifically mentioned were seismology and certain fundamental aspects of human behavior. It was pointed out that in future geological science, examination of crustal movements in operation would have important bearing upon our interpretation of the nature of the Earth. In consideration of the second group of researches it was suggested that carefully planned investigations in various aspects of biology now under investigation in the Institution would have value for interpretation of some of the more important problems in human behavior.

Two committees of distinguished investigators were invited to participate in examination of the problems proposed. In the course of the past eight years both lines of inquiry have been followed continuously. Both studies have now reached a point at which they have in a considerable measure attained the goal as originally visualized.

The committee of investigators in geology, geophysics, physics, and mathematics who were invited to participate in studies of seismology carried out a program which was concerned with development of new types of instruments, and with the setting up of projects for intensive study of specific regions on the basis of new methods. It has interested itself also in seismology as a world study related to the general problem of crustal movements. The results attained from year to year are noted in the reports of the President and of Dr. Arthur L. Day, Chairman of the Advisory Committee in Seismology, in the volumes of the Year Book since 1921.

For the investigation of certain special aspects of the problem of seismology it was considered important to organize a special program centering in a laboratory in Southern California. Through the cooperation of many agencies, including especially California Institute of Technology, such a plan was put into operation under extremely favorable conditions.

As a part of the plan of development arrangement was made to bring together the Advisory Committee and other specialists in this field for examination of the whole program as soon as the work should be sufficiently advanced to permit adequate examination of the mechanism in operation. The proposed conference was held during a period of two weeks in October of 1929. It resulted in a most interesting review of the status of investigation. The results of the conference emphasize the significance of this program as it has been formulated.

With this experience of several years in operation of the plan for seismological study in California, and the extremely

important review of the project by the Advisory Committee, the status of the work is so clearly defined as to make it evident that continuing development of research in this field will have large significance in geological science and its human application.

The investigations which have related more particularly to other parts of America, and to special localities in other lands, as illustrated by the work of Dr. Willis in Chile, Asia Minor, and Central Africa, have also illustrated the importance of correlated researches and carefully planned work of the cooperative type.

Operation of the Committee on Human Behavior has been even more informal than that of the Committee on Seismology. The meetings in 1922 and 1923 had as their major objective an attempt to define features of the problem of fundamental human reactions which might be reached to best advantage through studies of prenatal development and of the earliest stages following birth. It was recognized that certain of the aspects of development of the nervous system and its reactions in these early stages would have great importance.

Of the several phases of the problem the Committee expressed its view as to the exceptional interest, first, of an investigation of development of the morphology and physiology of the embryo with particular reference to reactions of the nervous system; second, as to intensive study of the reactions of the newly born individual; and third, as to the study of corresponding reactions of other organisms, especially those of types closely related to man. In the effort to follow out these types of research the Depart-

ment of Embryology of the Institution was recognized as the natural instrument for furtherance of studies of the first group. The progress through this Department in the field, considered of such importance by the Committee, presents a record in which the Institution may well have pride. The study of development of higher animals through this laboratory, as illustrated in the work of Dr. Hartmann in his research on monkeys of the macaque type, is one of the significant contributions in this field.

In study of the corresponding reactions of higher organisms related to man, special consideration was given to a program by which Dr. Robert M. Yerkes aimed to develop facilities for research on the higher anthropoids under conditions favorable for breeding and for extended study. In another direction an effort was made to assist in the organization of stations at which, for purposes of special research, the gorilla might be examined under the conditions of its original habitat.

The first of these two programs relating to study of higher animals similar to man has been realized as the result of establishment of research on a most satisfactory basis by Yale University, with the support of the Rockefeller Foundation. The second project, relating to study of the gorilla in its normal environment, is realized by the extremely significant action of His Majesty, the King of the Belgians, in setting aside in Central Africa an area, originally pointed out by Mr. Carl Akeley, which is exceptionally well fitted to be a preserve for biological and psychological studies of certain aspects of this peculiar fauna.

An earlier report to the Trustees directed attention to the marking off of the first quarter century since formal establishment of the Carnegie Institution in 1902. **Twenty-five Years' Research in Biological and Physical Sciences** In order to give adequate opportunity for touch with the many agencies cooperating with the Institution, occasion was planned for giving consideration to the development of research in its various phases through the work of certain of the Departments. In accordance with this plan, initiation of specially organized activities in the biological sciences, and their relation to the Institution as a whole, was celebrated through the Department of Genetics at Cold Spring Harbor on May 31, 1929. Investigations in the field of the physical sciences, with their broader relations in the Institution, were emphasized on August 26, by utilization of the visit of the ship *Carnegie* to San Francisco harbor.

This review of the program and activities of the Institution on occasion of these two meetings is of exceptional importance when one attempts to visualize the plans, procedure, and the results of the two and one-half decades of intensive work. The statement of progress, and the present status of researches has an importance which may not be overestimated in considering the responsibilities of the Institution as we look into the corresponding period which we are entering.

The addresses delivered on the occasion of the meeting at Cold Spring Harbor and on board the ship *Carnegie* in San Francisco present an exceptionally interesting picture of the Institution's work. As a basis for consideration of future policy they have the value of varying points of view held by persons who have had long and intimate

contact with our researches. So important is this visualization of the accomplishment of the Institution that these addresses are included as a part of the report to the Trustees.

*Address by John C. Merriam, President,
at Cold Spring Harbor*

The founding of the Carnegie Institution of Washington was of peculiar significance as an influence turning attention toward advancement of knowledge, as contrasted with its restatement or transmission. The establishing of an agency for this specific purpose did not indicate that such activities were considered either more or less important than educational work. It presented rather a coordinate or supplementary program, which would naturally gear itself closely to that of institutions designed initially for the work of education, or for other special applications of knowledge.

A group of the principal departments originated in 1904. Among them were Terrestrial Magnetism, Mount Wilson Observatory and Experimental Evolution. The last of these formed the basis for development of the present department of genetics. In the history of the Institution many types of organization have been used, and there have been numerous changes in statement of program. So the contribution of Mrs. Harriman, through gift of the Eugenics Record Office with its generous endowment, led in 1921 to union of Eugenics and Experimental Evolution in the Department of Genetics.

In somewhat similar manner the Division of Plant Biology, established in 1928, shaped itself to embrace the work of six sections, including physiology of growth, photo-

synthesis or the utilization of solar energy by the plant, classification and its relation to heredity and environment, studies on the influence of aridity, the section concerned with relationships to environment, and one devoted to the history of plants.

Development of the Institution illustrates what have seemed to be the needs of organization in attempting to secure the largest measure of return in investigation. Recognition of research as in itself an essential human activity had not attained the wide acceptance of the present decade, and much of the effort of the Institution was given to support of investigation wherever opportunity might be found. The interest of Mr. Carnegie in discovery of genius or the exceptional man found expression in numerous special grants, designed generally for personal work in specified fields.

With continuing study of opportunities for constructive work it was apparent that, in addition to the discovery of genius, advance of knowledge depends in some measure upon the possibility of bringing into research a degree of cooperation comparable to that which has been broadly characteristic of human relations in the advance of civilization. Out of this idea arose a type of department making possible concentration of effort upon a major problem, and opening the way also to effective advance of genius working in favorable relation to other coordinate interests.

From the earlier trend of the Institution toward extreme and sometimes isolated specialization, the more fully appreciated unity of knowledge in present-day thinking has brought once more a recognition of the interdependence of all scientific groups. Cooperative researches, including the most widely separated departments and investigators, have

developed a unity of interest and operation within the institution. They have brought into close relationship many elements which seemed only remotely related in objectives, and were widely separated geographically. In general the community of interest developed is at least as intimate as that which obtains within the spatially narrow limits of a campus. So we see the geophysicist and astronomer make plans for joint spectroscopic study of gases flaming from the inner earth; we find the physicist, chemist and astronomer turning their concentrated interest upon the crucible of the sunspot or the spectra of remote nebulae; in biology the physicist and geneticist unite to wrest the secrets from the chromosome; in another region the plant physiologist, the mathematical astronomer, the paleobotanist, the archeologist, and the meteorologist enter together upon study of varying patterns in the rings of a fossil tree, in order to learn the habits of the Sun in radiation of its energy in a remote geological period.

To-day we find the Institution utilizing all the major types of activity that have arisen in the quarter century experiment of its organization. There are still widely ranging special grants. Great departmental activities still represent concentrated effort in specific fields. The increasing mutual interest among research groups has not diminished the initiative of the individual. With the passing of time the element of broader cooperation within the Institution has made more effective both the special concentration on particular projects and the development of that wider view so essential in long-continued research operations.

As the Institution developed and research production attained considerable volume, it became clear that one of

the greatest responsibilities related to the making of results available for others. Whether this concern the investigator, the general student, or the intelligent citizen, there is increasing realization that if the treasures obtained are hidden in labyrinths bounded by unmeasured walls of printed pages, they may bring relatively small contribution to the community which makes possible the joy of this work.

In activities concerned with the field of the unknown, it will always be difficult to devise arrangements by which the information secured can be disseminated directly to those for whom it has largest use. But it is at least true that in the work of the Institution, each year sees real increase in effectiveness of statement, interpretation and distribution of materials. This applies not only to means used in reaching other specialists of the same field. It concerns as well the extremely important opportunity for communicating the results to students of related subjects, as also to the engineer or applier of knowledge, and to those with interest in knowledge for its own sake.

There has not appeared in these developments a tendency to turn Institution activities into the field of education as it is generally known. There is expressed the recognition of a responsibility for transmitting information regarding researches in progress in such manner as to attain as nearly as possible full value for the work as it proceeds.

The exhibits presented here to-day for the inspection of our friends illustrate one aspect of our view with relation to interpretation of research. They are the materials used in significant investigations now under way, and are planned to make a simple statement of the problems attacked. They are naturally in the main obtained from the laboratory at which we meet. They have special value because of the

opportunity to see them through the eyes of those who have conducted the investigations. In addition to indicating the character of the questions asked of nature they show the mode of approach in attempting to obtain answers. If the story could always be told as effectively as it is developed here, we should have advanced far in bringing research to a point at which the statement of its results would be at once an extremely effective form of education.

Concrete illustrations of the tendency to relationship among investigating groups of the Institution are furnished through several groups of exhibits. In the first building there is illustrated a research on the development of the mouse, and the influences which may affect these changes. It is interesting to note that the early growth stages, showing division of the mouse egg into complex cell-structure, have been furnished by cooperation with our department of embryology in Baltimore.

In the second building the exhibit, expressing the extremely important relation between the thyroid glands and the process of metabolism or energy production, is a joint investigation carried on by Dr. Riddle, of the Department of Genetics, and Dr. Benedict, of the Department of Nutrition in Boston. It contributes on the one hand to interpretation of metabolism, and, on the other, concerns that extremely important influence of the endocrine glands which plays so large a part in the later stages of development. By way of the Department of Nutrition, this investigation has also close relationship to still other researches in the field of nutrition which are conducted under support of this Institution by a distinguished group of investigators led by Dr. Mendel at Yale University.

The exhibit by Dr. Blakeslee, in the first or main building, representing through use of the jimson-weed one of the outstanding studies of the mechanism of heredity and mode of development in plants, has its intimate relation to much of the research furthered by the Institution's Division of Plant Biology. Especially closely does it touch the genetical researches of Dr. Belling, of that group, and the cooperative investigations of Dr. Babcock in the University of California.

The exhibit of Dr. Banta, in the first building, illustrating influence of various external conditions upon sex and other features in development, is one of the outstanding studies concerning relation between hereditary tendencies and environmental influences. Another Institution research of comparable type is that of Dr. Clements of our Division of Plant Biology. Dr. Banta's investigations are limited to study of a small group of organisms, "water fleas," examined by a wide variety of methods, and over a long period. The studies of Dr. Clements concern more especially the relationships of great masses of individuals in relation to their environment under conditions as they are found in nature.

In the Eugenics Record Office on the hill above us, Dr. Laughlin's unique genetical researches on inheritance of physical and psychological characters of the thoroughbred horse make direct contribution toward the study of inheritance of physical and mental characteristics in man.

But the background, against which these interesting accumulations of experience in observation of the horse must be projected, is formed by such researches as those on the fruit fly under the hand of Morgan, Metz and many others, on the larkspur as examined by Demerec, on the study of variation in maize, on the chromosomes of the

Jimson-weed, and through a new world of knowledge developing in many institutions engaged in research.

The special studies on human inheritance and development, constituting Dr. Davenport's culminating problems of the Eugenics Record Office, rest not only upon the broad foundation of researches extending from genetics through all biological and physical sciences, but connect us in other directions with a great field of inquiry on specifically human questions, presumably not to be solved solely by study of plants or lower animals.

One of the interesting illustrations showing relationship of this work to that of another Institutional activity is found in the cooperation between genetics and early American history in a study of race mixture. On the biological side there are involved the elements of inheritance through the chromosome, and the influence of the ductless glands upon development. The biological researches lead into investigations of mental traits and the consideration of human thinking and emotion, in which science has done little more than to lay out a region where it expects to make progress by the scientific method.

On the historical side of the work we see another group of students slowly but surely bringing together the kaleidoscopic picture of human experience. Essentially it seems an expression of the potentiality of man in nature with respect to change in accordance with law.

While genealogy, as sometimes interpreted, appears to look to the past as a justification for what exists, history tends to see its much longer record not merely as justifying what is, but as the evidence of a great becoming.

History would admit the absence of value in consideration of a past from which there comes no lesson, or of things

for which there is no remedy. It is good philosophy, as well as good psychology, to turn away from that which can not be corrected. It is also true that, taking human experience in the large, the joy of living and of being will not depend alone upon the manner in which what lies before us functions at a given moment. Two of the greatest truths in science concern, on the one hand, the unity of nature in the operation of its laws, and, on the other, the evidence that what we call stability of form or function is found only by those who see the universe, or any part of it, as an illumination of experience corresponding to the vision of a wind-swept forest under a lightning flash.

With what we know of nature and of man, it might appear that one who not only learns to know the form and functions at a given moment, but is able to see also the controlling modes of change, might well become master in the universe.

And finally, as wide as may be the range of these researches and the relationships which I have attempted to sketch—chromosome, mouse, thyroid of dove, horse, man—we find them balanced against each other as complementary elements in method and in point of view. It is through this kind of breadth of vision and mutual support that combined efforts of the many and varied institutions, such as are represented here to-day, may hope ultimately to obtain a clear and verifiable picture of the world about us and of the place which man has in it.

*Address by Professor Edwin G. Conklin,
at Cold Spring Harbor*

Anniversaries like this are occasions of retrospect as well as of prospect. The marvelous progress in all fields of science during the past twenty-five years is probably greater

than in any other century in the world's history. In large part this is the result of the general recognition of the importance of research and the munificent support which it has received during the past quarter century. The research spirit has been present in man from time immemorial; indeed it is as old as the race of thinking men. It is mentioned in the book of Proverbs where it is said: "It is the glory of God to conceal a thing, but the honor of kings is to search out a matter." But until recently opportunities for detailed, minute and continuous researches have been very limited.

Many colleges and universities that are now important centers of research made little provision for it twenty-five years ago. They were glad to say that their professors were conducting original work since this was good advertising, but those professors in general conducted their studies in the tag ends of their time and largely at their own expense. Most of us remember how professors used to talk about their research as "my own work," whereas teaching and administration was the university's work. It is only within recent times that this has changed and universities in this country have come to recognize that research is as important a part of the work of a university as teaching, and that both must go forward together in order that education and information may properly advance.

The Smithsonian Institution, founded in 1846, was probably one of the first institutions in America that was organized for the purpose expressed in the fine words of its founder, "For the increase and diffusion of knowledge among men." Other institutions more or less concerned with research were the learned societies, academies and museums. But they also had other functions, and research

as we now understand it was a relatively minor part of their programs. But at the end of the last century and the beginning of the present one there came a great impetus for research work for its own sake, and at this auspicious time the Carnegie Institution of Washington was established.

During the past twenty-five years research institutions and opportunities have multiplied abundantly, and they have introduced what may truly be described as a new era in human history. There is now universal recognition of the importance of research, not only for the increase of knowledge for its own sake, but also for the preservation and promotion of national welfare. This spirit of the new age puts upon those who are engaged in research and upon its promotion a tremendous responsibility. We have educated the public to recognize the supreme importance of scientific investigation; it remains to be seen whether we can convince the public that all the effort and expenditure which has gone into such study is justified. When I read in the newspapers some of the lurid representations of what has been accomplished by research, and more particularly of what we may expect in the near future, I confess to the feeling that there is bound to be some disappointment when these extravagant expectations fail to be realized; when the public is informed, as it sometimes is, that scientists have reached the conclusion of the whole matter, that their knowledge is fixed and final, I know that they are being misled, for the scientist knows, better than any other perhaps, that his knowledge is tentative and that he never reaches the goal toward which he travels. Like the El Dorado of the early conquistadors, that goal ever lies beyond the next range of mountains. But to the real scientist this

is a challenge rather than a discouragement, for, as Robert Louis Stevenson so beautifully said, "To travel hopefully is a better thing than to arrive, and the true success is to labor." Science travels hopefully and will continue to do so as long as civilization survives.

A retrospect over the field of biology shows three great eras past and one in progress at the present time, though, of course, these eras are not sharply divided and there is a large amount of overlapping. First of all, there was the era of exploration and of classification, and during this period emphasis was placed on the differences that exist among species, phyla, kingdoms. Botany, zoology and physiology were treated as distinct and independent sciences.

Then came the era of comparison, of comparative anatomy, embryology and physiology. During this period emphasis was placed on homologies and resemblances rather than differences. Morphology and physiology still remained as independent sciences, but botany and zoology were seen to have very much in common.

The third era of biological progress was one of generalization and speculation regarding evolution, heredity and variation. It was characterized by the marshalling of known facts regarding these subjects by Darwin (1859), Galton (1869), Weismann (1885). Speculation regarding these subjects flourished mightily. Phylogenetic trees for every group of the animal and plant kingdoms were constructed largely out of the imagination. Discussions were rife concerning the ancestry of vertebrates or of arthropods, or of many other groups of animals or plants. Hypotheses were invented to explain supposed facts of heredity or variation which had no real existence, and in general specu-

lation was inversely proportional to evidence. Inevitably there was a growing dissatisfaction among men with scientific instincts against these mere speculations—dissatisfaction which was expressed emphatically by Bateson and Whitman, and many others. I well recall a statement of the late Professor Watase, of the Imperial University of Tokyo, which expressed the opinion of many other workers with whom he was associated at the Marine Biological Laboratory at Woods Hole, "I am through with this whole phylogeny business."

The present era is one of experiment, of both analysis and synthesis, of a union of morphology and physiology. It began in the last decade of the nineteenth century with the rise of "Entwicklungsmechanik" under Roux (1890), the "Experimental Morphology" of Davenport (1897), and the "Experimental Evolution" of DeVarigny (1892). Biology was no longer a mere collection of facts nor of speculations about those facts, but rather an analysis of causes. The genesis of individuals and of species was then and is still the great problem upon which biologists are engaged, but continually it is being attacked by new and more accurate methods.

In 1900 came the rediscovery of Mendel's great work on heredity, and in 1902 came Bateson's translation and additions to this work, and the new era was in full swing. At this auspicious time came the establishment of the Carnegie Institution of Washington, "to encourage in the broadest and most liberal manner, investigation, research and discovery, and the application of knowledge to the improvement of mankind."

Professor Osborn had said in 1890, "When we have reached a heredity theory that will explain the phenomena

of inheritance, the method of evolution will itself be a problem of the past." The principles of Mendel furnished such a theory, and in May 1902, Dr. C. B. Davenport, then associate professor of zoology at the University of Chicago, submitted plans to the trustees of the Carnegie Institution for the establishment of a "Station for Experimental Evolution." At nearly the same time, the late Dr. A. G. Mayer proposed plans for a "Department of Marine Biology," and shortly after Dr. D. T. MacDougal proposed the establishment of the "Desert Botanical Laboratory." All of these projects were approved by the trustees, and later they established the "Nutrition Laboratory" under the direction of Dr. F. G. Benedict, and the "Department of Embryology" under the direction of the late Dr. Mall. Thus the Carnegie Institution has established five departments in different branches of biology, and in addition it has supported the research work of many biological investigators not connected with any of these departments. It is probably true that the work of these departments and investigators has done more to develop this new era in biology than has that of any other institution in the world.

It would be impossible in the time at my disposal to comment upon even the most important investigations which have been carried on under the auspices of the Carnegie Institution, and it would be invidious in me to attempt to estimate the value of these different lines of work. Coming down on the train this morning it seemed to me, as I talked with many members of our party, that almost all of them, who are now scattered over the length and breadth of the land, had at one time or another been workers at this

REPORT OF THE PRESIDENT, 1920

station. But without attempting any complete *statement* regarding the work of the station, it is fitting that I should mention a few of the outstanding workers and their investigations.

Dr. George H. Shull informed me this morning that he was the first member of the staff of the Station for Experimental Evolution to arrive on the ground in May 1904, and very soon thereafter he began his extensive work on heredity and mutation in the evening primrose and other plants, and also on the increased vigor of hybrids. Associated with this work was the really epoch-making discovery of Miss Lutz that different numbers of chromosomes are found in various mutants of the evening primrose. It was thus established that mutations may be due to changes in the number of chromosomes as well as to intrachromosomal mutations.

Dr. Davenport's extensive studies on the inheritance in man of feeble-mindedness, epilepsy, color of eyes and hair, skin color in negro-white crosses, twins and many important human traits have contributed greatly to our knowledge of these subjects.

Dr. Laughlin's studies of the racial stocks in our population and among the inmates of custodial institutions and on the eugenical aspects of sterilization have formed the basis of important reports to Congress. They were at first conducted in the Eugenics Record Office, established by the generous cooperation of Mrs. E. H. Harriman. In 1920 the Record Office was combined with the Station for Experimental Evolution under the title of the "Department of Genetics," and the work of the office has been expanded so as to include important studies on heredity in certain domestic animals, particularly the race horse.

I must mention also Dr. MacDowell's important investigations of the transmitted effects of alcohol on rats as well as on the rate of growth in mice; Dr. Little's studies on the inheritance of cancer in mice; Dr. Riddle's demonstration of a chemical basis for sex differences in pigeons as well as a study of the effects of endocrines upon sex and metabolism; Dr. Metz's discoveries regarding the cellular basis of heredity in different species of flies, a real comparative study of chromosomes and genes in different species and genera; Dr. Banta's studies of sex intergrades in the water flea; Dr. Blakeslee's investigations of sex in moulds; and last, but not least, the remarkable discoveries of Blakeslee and Belling on the many mutants of jimsonweed, and the cellular basis of these mutations.

This is a very incomplete list of some of the remarkable accomplishments of this department. These studies are spread over the living world from moulds to man, and yet all form an integral part of the original program proposed by Dr. Davenport, namely: "the study of variation, inheritance, adjustment, as factors of evolution." The experience of this station demonstrates the great value of prolonged and continuous work on well-selected forms. It fulfills the purpose of the Carnegie Institution "To encourage in the broadest and most liberal manner investigation, research and discovery, and the application of knowledge to the improvement of mankind."

*Address by John J. Carty,
at Cold Spring Harbor*

To-day we are meeting to celebrate the twenty-fifth anniversary of the inauguration of the research activities of the Carnegie Institution, and it is my privilege to address

to the members of its Department of Genetics a few words of appreciation of the great work which the Department has undertaken, and to congratulate its members upon the distinguished results which they have already achieved.

Among the many beneficent foundations established by Mr. Andrew Carnegie, the Carnegie Institution of Washington must always hold a foremost place. Founded by him "to encourage in the broadest and most liberal manner investigation, research and discovery, and the application of knowledge to the improvement of mankind," it has always been guided by the fundamental purpose of the founder—the conduct of scientific research for the improvement of mankind, and the achievement of the higher welfare of the individual.

It is fortunate for the carrying out of the great object for which our Institution was created that we have as its president and guiding spirit that distinguished scientist and philosopher, Dr. John C. Merriam, who is devoting his life to the improvement of human affairs and the establishment of the ways of peace, for which our great founder so earnestly labored and which he so fervently desired.

It has been my good fortune to be associated with Dr. Merriam as one of the trustees of this Institution, and like all who have the privilege of working with him I have marveled at his comprehensive knowledge of the sciences, and have felt the influence of his great wisdom and scholarship. While by the nature of his duties he is constantly active in the prosecution and coordination of scientific research in all of its branches, he never loses sight of the fact that the ultimate integration of scientific discovery and

research will achieve its greatest purpose when applied to the problem of the human individual.

To this problem, under the leadership of Dr. Charles B. Davenport, those distinguished scientists who constitute the staff of the Department of Genetics are directing their energies. I will not undertake to describe their work, for these master scientists are soon to take us through their laboratories where, in their own way and far better than I could do, they will explain the nature of their problems, their method of attack, and exhibit—all too modestly, let me warn you—some of their latest achievements.

It is difficult at first sight to understand what good is to come from growing jimson-weeds in clay pipes and thimbles; from studying the color of the eyes of insects, and the size of the wings of different species of flies, and noting the behavior of doves, and the form of the head of "water fleas." But these and many other experiments which might at first seem trivial and of no practical value are all undertaken because they are calculated to throw light on the unsolved problems of heredity and environment, and because they may yield scientific knowledge of profound importance in solving the problem of man himself.

The awful spectacle of the increasing numbers of the mentally sick, the prevalence of nervous diseases, and the generally disturbed condition of the nations have caused many to believe that we are headed in the wrong direction, and that our ideals should be those of the so-called simple life, or that we should seek to attain to the static condition of ancient China. Were it not for my faith in the ultimate success of such researches as you are conducting in this Institution, I believe that I too would share these views and

be inclined to the opinion that in merely material progress we had gone far enough—perhaps too far, or too fast.

While I have frequently asserted that human behavior presents the most important and the most formidable problem of all the ages, I believe that its solution can be achieved. While in this problem we should not ignore the claims of religion and philosophy, it would be a mistake to conclude that we have gone too far and too fast, and that we must restrict the progress of science in material things. On the contrary, we must accelerate our progress in all the sciences, for the knowledge thus to be gained will be required in preparing the individual man to function as a sane and peaceful unit in the ultimate social organism. I believe that the problem of human behavior can be solved, but not without profound and prolonged researches which shall bring to bear upon every phase of the subject all of the resources of science.

In order to solve the problem of the human personality we must push forward the advances of pure science in all directions without exception. This is the great mission of the Carnegie Institution which it is carrying out with the highest distinction. The pure scientist in whatever field he may be working is an explorer who is constantly extending our knowledge of the realities of our environment. The applied scientist is providing agencies so that we may adjust ourselves to these realities. By the aid of that unified knowledge which should be the aim of philosophy, education must expound the principles by which the individual shall make this adjustment.

In carrying out this campaign of research directed at the human problem, we must not confine ourselves to the oper-

ations of the biologists and others engaged solely in biological or medical research. We must encourage and utilize the work of the chemist and the physicist which is perhaps often conducted without any conscious regard to the human problem. The work of the physical scientist has already been of priceless importance in forwarding the work of medical research. Numberless examples of this are to be found. The microscope, the spectroscope and the X-rays are but a few of those that I may mention, to say nothing of those recent contributions of the chemist in analyzing the wonderful substances produced by the ductless glands, the functions of which affect so profoundly the health of the human body. This list could be extended indefinitely.

Even the astronomers are contributing towards the solution of the problem of the human personality. At the Mount Wilson station of the Carnegie Institution in California, and at the California Institute at the base of the mountain, a distinguished group of scientists endowed by the Carnegie Institution is conducting a systematic attack on the problem of the ultimate constitution of matter. On the mountain, the astronomers are observing in the sun and in the stars and in the nebulae not only worlds in process of evolution, but what is most astonishing, the evolution of the elements themselves. At the base of the mountain, the chemists and physicists are reproducing upon the earth, with increasing success, conditions which have been discovered in the depths of the universe. They are doing a marvelous work, and are achieving results which in the years to come will be of the utmost value in solving the problem of the human individual.

When these and other scientists working in different parts of the world have progressed in the mastery of the knowledge of the structure of the atom, when consequently perhaps some physicist devises a superoptical method which may enable us to view on the largest desirable scale the details of the animal cell, we shall then have a contribution of incalculable importance to the human problem.

To me, this celebration to-day is an event of the deepest significance, for it indicates the beginning of a new era of social development. As Trotter so well puts it:

The method of leaving the development of society to the confused welter of forces which prevail within it is now at last reduced to absurdity by the unmistakable teaching of events. The conscious direction of man's destiny is plainly indicated by Nature as the only mechanism by which the social life of so complex an animal can be guaranteed against disaster and brought to yield its full possibilities.

A gregarious unit informed by conscious direction represents a biological mechanism of a wholly new type, a stage of advance in the evolutionary process capable of consolidating the supremacy of man and carrying to its full extent the development of his social instincts.

Human progress need no longer be left solely to chance. By the aid of science it can be brought under our conscious control.

So vast are the problems of this control which lie ahead of us and which can be solved only by the aid of science that the total activities of the Carnegie Institution, great as they now are, should be increased a hundredfold. Scientific research in our universities and elsewhere, conducted solely for the advancement of knowledge, should be increased in like measure. If this is done, I believe that in the fulness of time by further scientific discoveries the physical develop-

ment of man will be improved, that many diseases will be entirely eliminated, and that immunity to the others will be achieved, and that feeble-bodiedness and feeble-mindedness will disappear.

In concluding, let me say that if we rightly interpret the work of these scientists which we are briefly to examine to-day, we shall find that it is directed ultimately to the overcoming of the defects both of body and mind which are found in the individual man, and which now prevent him from properly performing his function as a member of society. We shall also I think be made to feel that in the great plan of creation, the highest part has been assigned to man; for he must direct the development of that social organism which has been foreshadowed "with its million-minded knowledge and power, to which no barrier will be insurmountable, no gulf impassable and no task too great."

*Address by Dr. Henry S. Pritchett,
on Board the Ship "Carnegie"*

The Department of Terrestrial Magnetism of the Carnegie Institution is world-wide in its operations. It is the child of the Division of Magnetism of the U. S. Coast and Geodetic Survey and, as I happened to be superintendent of the Survey in 1899 when its work was expanded so as to undertake a systematic magnetic survey of the country, I have been asked to give some account at this meeting of the work in terrestrial magnetism carried on by the Coast Survey and whose development led ultimately to the larger project for a magnetic survey of the whole world.

The Coast Survey, although formally organized in 1816, dates back to the days of Thomas Jefferson and his great Secretary of the Treasury, Albert Gallatin. Its original

field of activity was defined by its title. It was a survey of the coast, and its purpose was to aid commerce by providing accurate charts showing the configuration of the coast and the depth of the adjacent ocean, so that navigation might be safe to vessels of all descriptions. Its mandate from the government related to all the coasts under the domination of the government of the United States and its mission might almost be described in the words of the Corsair of Lord Byron,

Far as the breeze can bear, the billows foam,
Survey our empire.

For the first five or six decades of its history, it remained a coast survey, but even in that day the making of a nautical chart involved some knowledge of the magnetic forces on the Earth's surface, for the compass was in constant use in navigation.

The strength and direction of the magnetic force in the Earth's field in horizontal and vertical planes are referred to as magnetic elements and vary from place to place, having also a slow progressive change from year to year. From its earliest work, therefore, the Coast Survey had to concern itself with the determination of the magnetic elements along the coast and of their changes. The primary purpose of such observation was to serve the needs of navigation and of survey. It is interesting to note that in our day air navigation imposes a still sharper demand for accurate knowledge of the magnetic elements.

As time passed, and the whole of the United States was settled and occupied, it became clear that a triangulation and a magnetic survey of the entire country would be necessary. The Coast Survey, therefore, was

ordered to assume the functions of a Coast and Geodetic Survey in order that it might meet this continental need.

Up to the beginning of the present century the work of the survey has been confined mainly to these observations of the magnetic elements for the direct service to the navigator and to the surveyor. It became clear, however, by that time that it would be necessary to carry out not only a far more extensive survey of the whole United States, but that permanent magnetic observatories should be established for continuous observation of the magnetic forces. This was the situation when I came to the Survey in 1897.

In the general examination of the various departments of the work of the Survey which the President and the Secretary of the Treasury had desired me to make, the question of the magnetic survey was involved. In consultation with my colleagues of the Coast Survey, we decided to ask Dr. L. A. Bauer, who had formerly been connected with the survey under Mr. Schott, to make a report on the state of our knowledge of terrestrial magnetism and to indicate the sort of organization which, in his judgment, might be set up in the Coast Survey to deal with this problem from the standpoint both of its scientific value and of its commercial applications.

Dr. Bauer submitted to the superintendent of the Coast Survey a plan which contemplated the observations of the three magnetic elements over the whole country at stations that were from thirty to forty miles apart. In addition to the stations in areas of magnetic disturbance, certain other stations were to be occupied for repeating the observations in order to determine the secular changes of the magnetic elements, and finally a limited number of magnetic observa-

tories at fixed stations were planned where continuous observations of the United States magnetic field could be made and recorded.

The report of Dr. Bauer, after a full discussion by the scientific men of the Coast Survey, was recommended, practically in the form in which he offered it, to the Secretary of the Treasury who approved the plan and approved, likewise, the application to Congress for a sufficient appropriation to inaugurate it. This appropriation was granted by Congress and a new division, known as the Division of Terrestrial Magnetism, was set up in the Coast and Geodetic Survey in May 1899. Dr. Bauer was invited to undertake this work and became the first director of the division. He had, as an associate, Mr. D. L. Hazzard, who succeeded him in the direction of the Division of Magnetism when Dr. Bauer resigned the work in 1904.

It ought to be said that the establishment of the Division of Magnetism, as well as the development of the Bureau of Standards from a small office of weights and measures, would not have been possible without the cordial and effective cooperation and support of the Secretary of the Treasury, Mr. Lyman Gage, and the Assistant Secretary, Mr. Frank A. Vanderlip. As Jefferson's great Secretary of the Treasury, Albert Gallatin, had stood back of the Coast Survey in its early beginning, so Mr. Gage stood back of it a century later in its effort to meet the growing needs in a nation that had expanded over a whole continent.

During the period following the creation of the new Division of Terrestrial Magnetism, five observatories were established and put in operation. Special buildings were erected for the observatories at Cheltenham, Maryland;

at Sitka, Alaska, and at Ewa in Honolulu. Similar buildings were erected later in Porto Rico.

Besides fulfilling the immediate needs of our own country, the magnetic observatories of the Coast and Geodetic Survey have cooperated with other magnetic surveys and observatories throughout the world and have rendered important contributions not only to the practical work of surveying and of hydrography, but also to our knowledge of the nature of that mysterious magnetic field which surrounds the Earth. The survey began also the determination of the magnetic elements at sea but, inasmuch as the observations were made on steel vessels, the difficulties of accurate results under such circumstances were very great.

Meantime it became clear that since the problems of terrestrial magnetism are world-wide, there would be necessary some organization of a study of the magnetic elements and of their variations over the whole world. When, therefore, the Carnegie Institution of Washington was founded in 1902, and its trustees invited various scientific men to suggest projects which they believed to be of great importance, Dr. Bauer presented a plan for a world-wide study of magnetics. His plan was adopted by the trustees of the Carnegie Institution and he was invited to undertake the direction of that work. In 1904, therefore, he transferred his activities from the Division of Terrestrial Magnetism of the Coast and Geodetic Survey to the Department of Terrestrial Magnetism of Carnegie Institution of Washington. This is a brief story of the process by which the Division of Magnetism, which began a hundred years ago in the Coast Survey for purely utilitarian purposes, has gradually resulted in the establishment of a world-wide survey

of the Earth's magnetic field. It is no small credit to the Coast and Geodetic Survey that out of its scientific work, planned originally for purely utilitarian purposes, there should have arisen two great scientific agencies like the National Bureau of Standards and the world survey of the magnetic field of the Earth.

The Earth is charged with negative electricity. Although this escapes constantly into the air, the Earth's charge is never permanently diminished, nor is the charge in the air increased. How the charge thus lost from the Earth is replaced has not yet been certainly explained and is perhaps one of the most important and far-reaching problems of atmospheric electricity still awaiting solution.

As an agency in the prosecution of this problem the non-magnetic ship, *Carnegie*, upon which we meet to-day, was constructed. Since magnetic iron in any form affects magnetic instruments, the *Carnegie* was constructed of wood with cotton fastenings. The small quantity of iron on board is in the engine room, far enough away to have no appreciable effect on the instruments. It has therefore been possible, through this specially constructed ship, to continue observations over a very large part of the United States surface where hitherto such observation could not be accurately made. That this service has been of enormous benefit not only to the mariner but also in our attempt to understand the forces of terrestrial magnetism can not be questioned. It is interesting to note that as this world-wide survey has gone on under the leadership of the Carnegie Institution, the Division of Terrestrial Magnetism of the Coast and Geodetic Survey has continued to cooperate with it in the most helpful manner. It is by such cooperation

that science makes its constant progress. On this day, therefore, when we celebrate the twenty-fifth anniversary of the Carnegie Institution of Washington aboard this unique vessel, it is both a pleasure and a duty to record our indebtedness to the Division of Terrestrial Magnetism of the U. S. Coast and Geodetic Survey of which this great enterprise under the direction of the Carnegie Institution is a daughter.

*Address by President W. W. Campbell,
on Board the Ship "Carnegie"*

If I were asked to name and describe the most wonderful fact known to man, my reply would be this:

As far as our observations and experiences go, every particle of matter in the physical universe—every atom and part thereof—is endowed with the property and the necessity of obeying the fundamental laws of nature. Our universe of stars, our own star, and our Earth in all its parts, have been developed through long ages, to their present states, under the guidance and compulsion of perfectly definite and apparently simple laws. We have no reason to suppose that those laws are ever set aside, or varied in the slightest degree. The operations of those laws are believed to be never capricious or undependable. In fact, the arbitrary and the capricious do not seem to exist in physical nature. Whether the arbitrary and capricious exist in human nature is quite another matter, but that is a bridge we need not cross to-day!

This Earth of ours, when measured in astronomic units of length and mass, is a mere bagatelle, a negligible thing;

but when measured in terms of human dimensions it is an enormous body.

Cutting a little notch in the Culebra ridge at Panama, a ridge only three or four hundred feet high, to let the ships pass through—that was a huge undertaking. Not all the developed wealth of the entire United States would suffice to level off a few small mountain peaks at the edge of Lake Tahoe, and use the resulting materials to fill the cavity now occupied by the waters of that lake!

This great planet of ours is still responding, in major degree, to the forces, to the laws, which controlled its evolution. There is nothing of greater importance to the well-being of the human race than that its universities and its other research institutions should determine the nature and the potency of those forces and the ways of those laws, so that the plans of man for doing the work of the world may be in harmony with them, and not in opposition thereto. Our engineers could compel the rapidly descending waters of a mountain stream to reverse their direction and go up hill, through pipes, to their source, but at what a heavy cost, day and night, day and night, and all to no good purpose. The same engineers could harness that stream and make its descending waters generate electricity and, by doing the work of the community, day and night, day and night, contribute to the comfort and happiness of men, women and children.

Now it took the people of this Earth a very long time to learn a little something about electricity and chemistry and biology; and scores upon scores of able investigators are still finding out new things about those subjects; not really new things, not new laws and new principles, but old ones,

immensely older than the hills, which had not yet been discovered—not yet uncovered—and brought to their notice and comprehension, and ours.

There are forces acting upon the Earth whose effects are undoubtedly of great significance, but whose origin and laws are as yet very imperfectly known. I here refer especially to the subjects of terrestrial magnetism and terrestrial electricity. As this little pamphlet, recently issued by the Carnegie Institution, says:

There exists about the earth a field of magnetic forces of which the origin is still unknown. The distributions and variations of this field present characteristics which are related not only to the magnetic and electric phenomena of the earth and its atmosphere, but also to solar and cosmic phenomena. The strength and direction of the earth's magnetism in the horizontal and vertical planes are referred to as the magnetic "elements," and these vary from place to place.

An exact knowledge of the way in which they vary is demanded for the efficient use of the compass in maritime and ærial navigation; and a study of irregularities of distribution, is one of the few means we possess for investigating the properties of subterranean masses. However, the values of the magnetic elements obtained at any point are not constant, but undergo periodic and irregular variations.

There is a diurnal variation in the pointing, a gradual shifting of the needle back and forth in a period of twenty-four hours, this diurnal shifting being greatest in summer and least in winter—obviously an effect, direct or indirect, of the Sun's heat. There is another shifting of the needle, back and forth, in an average period of eleven years plus, which evidently bears intimate relation with the periodicity of the spots on the Sun. Further, there is a long-period or

secular change in the pointing of the needle. At the Greenwich Observatory, in southeastern London, the magnetic needle in the year 1570 pointed 11° east of north; in 1660, ninety years later, its pointing was due north; in 1800 it pointed 24° west of north—a change of 35° in 230 years. Since 1800 the needle's pointing has been shifting easterly, until at Greenwich to-day the average reading is about 14° west of north.

Then there are two principal types of sudden fluctuations of the needle pointings:

First, those due to special conditions called "magnetic storms," which in their more intense forms are usually accompanied by auroræ, by electric currents of cosmic origin—frequently revealed on our telegraph and telephone lines which for a few hours are put out of use—and by especially active or large or numerous spots on the Sun; and

Secondly, those due to the near presence of magnetic materials in the Earth. In 1922, as the ship on which we were passengers was approaching the harbor of Broome, on the northwest coast of Australia, and through the courtesy of the Captain on the bridge, we watched the ship's compass needle vary its pointing through 70° and back again in the course of not more than three or four minutes of time. We were apparently passing nearly over a great subterranean mass of metallic iron ore, or other materials possessing magnetic properties.

Now these extraordinary magnetic happenings had long been studied, but chiefly by individuals working alone, and on land areas forming only a minute part of the Earth's surface. This problem of terrestrial magnetism, relating to the whole of the great planet upon which we reside, is

accordingly an extremely extensive, complicated and difficult one. The first step toward its solution consists in the acquiring of the facts; the making of millions of accurate observations of the magnetic elements upon the surface of the continents and the seas, and of the electrical elements in the depths of the waters and in the heights of the air. To complicate the subject, observations already made, no matter when, do not continue to fit their points of observation; the magnetic elements at any point of observation vary with the passing of time, as already stated. The problem is entirely too large for an individual: it is a problem for an institution, a continuing institution, of great financial resource.

We have heard anew, on this anniversary occasion, about the establishing of the Department of Terrestrial Magnetism in the Carnegie Institution of Washington, under the leadership of Dr. Bauer, in 1904, with definite purpose and commendable courage, to take up the study of this problem; and we have learned to-day about the good ships *Galilee* and *Carnegie*—something of their extensive cruises, back and forth, upon the seas, and just a little about the well-planned and well-executed activities of their staffs. The observations secured upon their decks have been supplemented, simultaneously, by similar observations made at thousands of land stations on all the continents except Antarctica. The very great number of accurate observations secured on land and sea and in the air and water have priceless value for the human race. The results thus far obtained from the study of these observations, results recognized by all students of the subjects as of very great importance, are but the first fruits of the heroic undertaking.

The commercial ships which are traversing the seas and making the whole world kin have during nearly two decades past been guided by charts whose magnetic elements are remarkably accurate, thanks to the work of the ship *Carnegie*. The staff of this ship upon which we are assembled discovered on its first cruises that the earlier charts used by the navigators were in error by astonishing amounts—approximately a degree as to the pointings of the compass in some parts of the intensively used north Atlantic trade route, and even as much as four, five and six degrees on some of the Pacific Ocean routes.

The extensive observations and the studies based thereon have established that “the entire Earth is charged with negative electricity. Although this escapes continuously into the air, yet the charge of the Earth is never permanently diminished nor is the charge of the air increased. This charge of the Earth fluctuates in a regular manner during the day and from season to season. These regular changes occur in unison at all places on the Earth’s surface. . . . The rate at which the charge of the Earth passes into the atmosphere can be calculated. For the whole Earth this amounts to a current of about 1,600 amperes, on the average. But how the charge thus lost from the Earth is continuously replenished has not been satisfactorily explained, and remains the most important and far-reaching unsolved problem of atmospheric electricity. . . .”

The knowledge gained by the Carnegie Institution in these fields will contribute generously to a better comprehension of some of the laws which have attended and will continue to attend the evolution of the Earth; to a better understanding of the interrelationships of the Earth and our

Sun, and quite likely to a better understanding of the inter-relationships of our Sun and its planets with the myriads of other suns in our own stellar system, and of our Sun and its planets with the myriads of other great stellar systems as represented by the spiral nebulæ distributed through wide space.

In closing, it gives me very great pleasure to express the conviction that no man ever made a better or more ideal investment in behalf of humanity's welfare than did Andrew Carnegie when he founded the Carnegie Institution of Washington. This is certified by the constant stream of dividends earned and distributed by the Institution's many component parts which conduct investigations in the physical sciences, the biological sciences, and the social sciences. Through the rich contributions made by the Carnegie Institution to our knowledge of these sciences, we are being greatly assisted in putting ourselves in harmony with our surroundings on the Earth and in the greater space about us, and we are bound to succeed the better in marching with the evolutionary current that is ever ready to serve us by joining forces with us.

Address by Captain J. P. Ault, on Board the Ship "Carnegie"

The plan of Dr. Louis A. Bauer, who organized this department twenty-five years ago, was to find out something more about the magnetic and electric state of this globe upon which we live, not only on the surface but also in the interior of the Earth and in the air above and in the waters beneath the sea. The thinking and progressive mind could not ignore the challenge of the mysteries which surrounded the Earth's magnetic and electric fields, not only in the fact of their existence but also in the untableted laws which

seemed to govern their many and unusual variations and their relations, near and distant, to other terrestrial and cosmical phenomena. We make constant daily use of these mysterious manifestations of nature, in surveying, in sea and air navigation, in commerce, in manufacture, in telegraphic and radio communication and in countless other ways. We seek to broaden and extend this use and to brighten the dark places by added knowledge.

The chief accomplishment from a visible and tangible aspect has been the completion of a world magnetic survey on land and sea, with its attendant contributions in geography, astronomy, meteorology and oceanography.

In this brief summary, the story of individual endeavor and enterprise, of invention and accomplishments can not be told. In the performance of this work many men visited practically all the countries of the world and the two vessels used in the ocean survey sailed many times over all the seven seas.

More than 180 expeditions have determined the values of magnetic elements at 5,800 land stations and 600 of these were repeat observations giving information as to secular-variations or change constantly taking place. The ten ocean expeditions have determined the magnetic values at 6,000 stations at sea, and secular-variation data have been secured at over 150 localities where cruises have intersected, involving from 2 to 10 stations at each intersection.

Continuous records of the changes in the magnetic elements have been made for ten years at our permanent observatory at Watheroo, Western Australia, and for seven years at Huancayo, Peru. These two observatories were established in the Southern Hemisphere to supplement the

work of other observatories maintained by the different countries of the world, chiefly in the Northern Hemisphere.

The investigation of the Earth's electric field has been confined chiefly to the ocean expeditions and to our observatories in Australia and Peru. The values of the atmospheric-electric elements have been determined daily at sea during the cruises since 1914 and continuous records of their variations have been made at these two observatories for about seven years.

Thus the department has fairly completed the picture of the distribution of the Earth's magnetic and electric fields over the surface of the globe and many additional facts have been recorded concerning the laws which control the variations in these fields.

In addition to the virtual completion of this general survey on land and sea, may I briefly outline some of the more specific contributions to the physical sciences made by the department during the past twenty-five years.

First, in theoretical studies, much progress has been made in locating the causes of the Earth's magnetic and electric fields and of their many variations which are constantly taking place, in establishing relationships between magnetic and electric and other cosmical phenomena such as polar lights, variations in radio conditions and changes in solar activity. Practically all variations in magnetic, electric, Earth current, radio conditions on our globe and in polar lights can be connected with some activity on the Sun. That these fields are modified when the sun's rays are cut off from a portion of the Earth and of its atmosphere during a total eclipse of the Sun by the Moon has been shown con-

clusively by the results of seven eclipse expeditions sent out by the department since 1905.

Considerable advance has been made in the study of the nature of magnetism and electricity and atomic structure. It has been found that certain bodies become magnetic due to rotation, and conversely that rotation may be caused by magnetization. These facts have been confirmed by extensive experiments made in the department's experimental laboratories at Washington.

During the past few years more attention has been paid to a study of the structure of the atoms and in devising methods and instruments for detailed experiments. To produce high-speed electrical particles, available voltages of 5,200,000 volts have been obtained and methods for handling and applying this power are being perfected.

Laboratory experiments also have proved the existence of the Kennelly-Heaviside radio reflecting layer and its height and variations have been determined.

In atmospheric electricity, a study of the ocean results shows that the daily variation in the Earth's electric charge, the so-called potential-gradient, is a function of universal time and not of local or Sun time. A similar variation occurs in the theoretical current induced by the action of the rotating magnetic field of the earth on charged particles coming into the Earth's atmosphere from the Sun.

These facts shed new light on some of the fundamental problems of cosmical physics.

More concretely, magnetic charts issued periodically by the various governments for the use of navigators have shown marked improvement. Twenty-five years ago, errors as great as 3, 5, 10 and even 16 degrees occurred in the

declination charts; 8 to 10 degrees in dip and 10 per cent in horizontal intensity. The charts recently issued are rarely in error more than 1 degree.

An international magnetic standard has been determined and adopted. Our standard instruments have been compared with those of practically every observatory in the world, so that now all observations may be reduced to the same standard and used in any general analysis or discussion without any uncertainty.

This leads to probably the most important factor in the department's contribution—the advance in instrumentation. Research in the physical sciences can go forward only as rapidly as new methods and instruments are designed. This has been particularly the case with this department. New design and new instruments have been the cause of progress. The man chiefly responsible for this advance is now our assistant director, Mr. J. A. Fleming. The ocean work called, and is still calling, for new designs to allow for improved results and for expanded programs. Land work and our new observatories have had similar histories. Especially is this true for atmospheric-electric and earth-current equipment. At no other observatory in the world is the equipment in these two branches so complete.

Some of these new instruments have been adopted by other countries and the department's influence has been felt in many ways, leading to improvements in methods and results, extension of surveys, increase in numbers of observatories and expansion of observatory programs. Among the factors exerting this influence may be mentioned the quarterly journal, *Terrestrial Magnetism and Atmospheric Electricity*, the prompt publication of results, the generous

support of expeditions with loaned equipment and training of observers, the personal contact through observatory intercomparison and through visits of interested scientists to our laboratory in Washington and through the visits of the *Galilee* and *Carnegie* to many parts of the world.

*Address by Dr. Walter S. Adams,
on Board the Ship "Carnegie"*

The return of the *Carnegie* from distant seas with all the store of information which it has collected can not fail to stir the imagination deeply. It has brought us knowledge of the electric and magnetic currents of the Earth, so vital to the mariner's compass, of life in the great depths of the sea, of the constitution of the ocean-floor, and of the mysterious winds of radiation which sweep the face of the waters from the depths of space. And yet this ship and the work of the men who have labored in it represent but one phase of the activities of the Carnegie Institution of Washington in promoting and extending the growth of knowledge. During the twenty-five years of the life of this great research organization there have been few branches of scientific thought to which it has not made notable contributions; and were one to attempt to define the field of its activity this could hardly be stated in terms less broad than as the history and development of life in all its forms, its relationship to its environment, and the nature of the physical world within which it exists.

One of the well-known younger writers of England in a skilful analysis of some of the aspects of modern life has stated that the progress of civilization is due to those who do the unnecessary work of the world. The author, the artist, the musician and the scientist are not contributing

directly to the satisfaction of the material wants of men, and it is in this sense that Aldous Huxley uses the term "necessary." But if the word is extended to include what is vital and needful to the mind and spirit of men, the craving for beauty and for knowledge so deeply implanted within us, the unnecessary work of the world in a material sense becomes its most precious heritage and the distinguishing factor in the progress of the race. The dark ages of mankind are recognized, not as the periods of decline in material comfort, but as those within which the creative faculties are temporarily eclipsed, and the light of learning and discovery is dimmed. It is probable that the conditions of living in Europe about the year 1000 A. D. were superior to those in ancient Greece, but as between the contributions of the two periods to the culture and intellectual life of the world no comparison is possible.

The space of twenty-five years covering the life of the Carnegie Institution has seen by far the most extraordinary development of the physical sciences for any comparable period in history. It has been a time of remarkable discoveries, but, even more important, it has been a time of synthesizing of results, of establishing general principles and rules, and of placing facts in their proper relationship to one another and to the fundamental laws of nature. The last quarter of the nineteenth century might be characterized as a period in which isolated facts were observed and collected; the first quarter of the twentieth century as one in which these facts and many others were explained on the basis of broad and far-reaching generalizations. Between the relative values to the progress of science of these two types of contribution there can be little comparison; and it is the

immense importance to research of new methods and new principles which makes the work of the bold but judicious imagination so essential a factor in the development of knowledge.

As an illustration of the value to science of a powerful and well-grounded theory, I should like to refer briefly to one taken necessarily from the field with which I am most familiar. If a metal like iron is melted and then vaporized in a furnace of very high temperature, and the light of the glowing gas is analyzed, it is found to consist of a great number of lines characteristic of this metal, and this metal alone. Hydrogen has its own set of lines, carbon another, and so for all of the ninety elements known to the chemist. These lines are found in the light of the Sun, the stars and even the immensely distant nebulae; and just as the chemist uses their presence in the analysis of materials in his laboratory, so the astronomer uses them to analyze the composition of the farthest stars.

The amount of observational labor devoted to the study of the spectral lines has been enormous. Their positions, their intensities, the nature of their variations and many other data have been catalogued, all in the realization that locked up in these lines is a wealth of information concerning the constitution of the atom and of matter which could lead to applications of the most far-reaching character. The key to the problem was provided by the theory of the atom developed by the great Danish physicist Bohr. This led at once to the first rational explanation of the mechanism by which an atom gives out light and radiation, and opened the way to the interpretation of essentially all that had previously remained unknown. Developments and appli-

cations have followed one another with amazing rapidity, the great mass of accumulated observations has been brought into a consistent and logical order, and the range of our physical knowledge has been steadily widened until it stretches from atom to Sun, from Sun to star, from star to universe. By its aid we can measure the life of a radiating atom in a star at the limits of our universe in billionths of a second of time, and the temperature in the interior of our Sun in tens of millions of degrees.

A second marked characteristic of recent developments in science has been the realization of the intimate relationship, we may even say interpenetration, of its various branches. No department of physical science is sufficient unto itself. Biology and astronomy lean heavily upon physics and chemistry; physics depends more and more upon mathematics; and, as the methods of statistical mechanics become more widely applied, the greater becomes the need for adequate check and control through the facts of observation. An excellent illustration is afforded by one of the important discoveries of recent years, that the molecule of oxygen, the basis of the whole system of the atomic weights of the elements, exists in two forms instead of the single form universally assumed. The discovery belongs to the field of chemistry; but the practical evidence was afforded by astronomical observations at Mount Wilson; and its interpretation is due to the theoretical physicists of the University of California working through intricate mathematical processes. I think it may justly be said that the Carnegie Institution has been a leader in the realization of this close interdependence of the various fields of science, and of the power for research of groups of coordinated investigators.

Many of us will see tomorrow at Stanford University the dedication of a new laboratory in which will center the studies of men of wide diversity of training who are joining in a common effort to solve many of the great problems of the life and growth of plants and their adaptation to environment.

A very interesting development in modern science has been the remarkable boldness in the use of hypothesis, and the success which in nearly every case has attended it. A period which has produced the theory of relativity with its profound implications in science and philosophy, and has solved the age-old problem of the source of energy in the universe through the well-established theory of the conversion of matter into radiation, is certain to rank high in any history of the triumphs of the human mind. Although a speculative hypothesis of itself is often futile, that which is founded upon the facts of observation, and is developed to keep pace with them, becomes frequently the most powerful weapon of research within the capacity of science to use. It is this application of the highly trained imagination to the facts of nature which has made so extraordinarily productive the years within which we are living.

In any summary of the contribution of physical science to society, chief stress is often laid upon the fundamental nature of the relationship of pure science to all inventions and processes which tend to increase the comfort and the productivity of men, and their ability to control and direct the forces of nature. The familiar example of the growth of the entire electrical industry of the world out of the scientific researches of Faraday is only one of innumerable instances. But the intangible effects of science are in many respects more interesting. Of its function in satisfying one

of the deepest interests of life, the joy of discovery and the love of knowledge, I have already spoken. In its influence upon the judgment of men, their reasoning powers and the skilful weighing of evidence, its value is extraordinarily great. But perhaps beyond all else is the kindling and stimulation of the imagination. The child clothes with his imagery the simple things of nature; the intelligent man finds the phenomena of nature wonderful beyond all conception, and in the reaction to them of the powers of his imagination he finds one of the most enduring values of life.

Of the many and varied contributions of the Carnegie Institution to physical science it is impossible to speak in detail. They form an integral and vital part of the history of knowledge. Its investigators have studied deeply into the mysteries of life and the development and modification of species; they have searched into the complex processes by which the animal and vegetable life of the Earth derives its growth and energy; they have added greatly to our knowledge of the past history of life upon the Earth, and have welded links in its unbroken chain; they have studied the powerful forces within the Earth, and have charted the magnetic field about it; they have numbered the stars and pushed far back the frontiers of the universe; they have penetrated deeply into the mysteries of matter and the world of space and time. Extending through all of these and many other investigations has been the realization of the unity of science and of the essential part it plays in the life of the race. On this anniversary of the establishment of the Carnegie Institution it may justly be said to have fulfilled amply the hopes of its founder in carrying the torch of learning and spreading its light among men.

REPORT OF THE PRESIDENT, 1929

FINANCIAL STATEMENT

The sources of funds available for expenditure during the fiscal year (including appropriations made by the Trustees, December

**Financial
Statement
for Fiscal Year
1928-1929**

14, 1928, and revertments and transfers made during the year), the amounts allotted by the Executive Committee during the year, and the balances unallotted at the end of the year are shown in detail in table A.

A—Financial statement for fiscal year ending October 31, 1929

	Balances unallotted Oct. 31, 1928.	Trustees' appropri- ation Dec. 10, 1928.	Revert- ments and transfers Nov. 1, 1928, to Oct. 31, 1929.	Total available 1929.	Executive Committee allotments 1929.	Transfers by Execu- tive Com- mittee.	Unallotted balances Oct. 31, 1929.
Large Grants:							
Early American History...	\$ 76,400	\$3,850	\$ 80,250	\$ 80,250			
Embryology.....	59,080	3,000	62,080	62,080			
Genetics.....	134,830	4,550	139,380	139,380			
Geophysical Laboratory...	176,244	9,000	185,244	185,244			
Historical Research.....	22,380	3,125	25,505	25,505			
Marine Biology.....	15,800		15,800	15,800			
Meridian Astrometry.....	38,540		38,540	38,540			
Mt. Wilson Observatory..	240,800	10,600	251,400	251,400			
Nutrition Laboratory.....	50,570	250	50,820	50,820			
Plant Biology.....	128,150	3,180	131,330	131,330			
Terrestrial Magnetism.....	189,370	27,000	215,370	215,370			
Yacht Carnegie.....	76,500		76,500	76,500			
Minor Grants.....	\$7,516.91	133,700	13,105.31	154,322.22	153,745		\$ 577.22
Publications.....	6,132.14	96,350	32,982.89	135,465.03	125,603.85		9,861.18
Administration.....		67,850	602.60	68,452.60	68,452.60		
Insurance Fund.....		1,500		1,500	1,500		
Pension Fund.....		40,000		40,000	40,000		
General Contingent Fund...	24,583.33	58,000	27,254.72	109,838.05	10,910.95	\$85,107.60	13,819.50
Sp. Emer., Reserve Fund...		68,500		68,500	68,500		
	38,232.38	1,673,564	138,500.52	1,850,296.90	1,740,931.40	85,107.60	24,287.90

CARNEGIE INSTITUTION OF WASHINGTON

The aggregates of receipts from interest on endowment, from interest on bond investments and bank deposits, from sales of publications, from refunds on grants, and from Receipts and Expenditures of the Institution to Date miscellaneous sources, for each year since the foundation of the Institution are shown by table B; the grand total of these to date is \$69,582,934.93.

B—Aggregate of financial receipts

Year ending Oct. 31.	Interest on endowment	Interest on bonds and bank deposits	Sales of publications	Refunds on grants	Miscellaneous items	Total
1902	\$250,000.00	\$9.70	.....	.....	\$1,825.52	\$251,835.22
1903	500,000.00	5,867.10	\$2,286.16	.....	101.57	508,254.83
1904	500,000.00	33,004.26	2,436.07	\$999.03	.....	536,439.36
1905	500,000.00	25,698.59	3,038.95	200.94	150.00	529,088.48
1906	500,000.00	27,304.47	4,349.68	2,395.25	19.44	534,068.84
1907	500,000.00	22,934.05	6,026.10	2,708.56	15.22	531,683.93
1908	550,000.00	17,761.55	7,877.51	25.68	48,034.14	623,698.88
1909	600,000.00	14,707.67	11,182.07	2,351.48	103,564.92	731,806.14
1910	600,000.00	10,422.78	10,470.25	1,319.29	54,732.45	676,944.73
1911	975,000.00	14,517.63	10,892.26	4,236.87	923.16	1,005,569.97
1912	1,100,000.00	31,118.41	11,496.13	1,658.88	96,035.01	1,240,308.42
1913	1,103,355.00	46,315.60	12,208.66	3,227.53	345,769.95	1,510,876.74
1914	1,105,084.17	59,298.63	11,402.40	7,819.70	577,305.77	1,760,910.67
1915	1,100,375.00	67,888.31	10,297.79	8,322.87	28,162.79	1,215,046.76
1916	1,100,375.00	83,626.38	12,544.16	1,450.12	153,204.40	1,351,200.06
1917	1,100,408.75	100,702.60	11,921.35	32,950.22	179,611.97	1,425,594.89
1918	1,110,427.45	120,464.02	9,921.00	39,833.23	255,354.60	1,536,000.30
1919	1,112,441.25	138,700.73	12,837.58	53,549.98	214,498.99	1,532,028.53
1920	1,112,441.25	159,559.03	18,393.79	4,088.63	176,249.81	1,470,732.51
1921	1,112,441.25	170,211.22	16,684.51	4,068.69	210,518.96	1,513,924.63
1922	1,112,504.52	175,021.09	14,081.84	9,395.66	34,527.38	1,345,530.49
1923	1,114,541.13	192,287.72	13,841.76	9,739.17	1,720,808.90	3,051,218.68
1924	1,115,187.58	193,368.98	11,994.21	18,663.38	409,712.28	1,748,926.43
1925	1,181,585.00	197,696.51	13,680.74	14,315.03	825,156.17	2,232,433.45
1926	1,156,795.00	199,418.02	14,039.02	44,766.64	167,898.35	1,582,917.03
1927	1,186,397.70	199,038.63	10,032.42	19,049.80	1,814,461.93	3,228,980.48
1928	1,496,737.48	218,755.01	10,924.25	31,144.42	26,068,636.68	27,826,197.84
1929	1,376,398.03	217,269.74	8,925.91	110,724.28	6,367,398.68	8,080,716.64
Total	26,272,495.56	2,742,968.43	283,786.57	429,005.33	* 39,854,679.04	69,582,934.93

* Of this amount \$34,942,359.12 came from the sale of bonds; \$51,265.74 from the Colburn Estate; and \$4,794,791.67 from the Carnegie Corporation of New York.

The purposes for which funds have been appropriated by the Board of Trustees of the Institution may be classified under five heads: (1) Investments in bonds; (2) large projects; (3) minor

REPORT OF THE PRESIDENT, 1929

grants and payments from Pension, Insurance, and General Contingent Funds; (4) publications; (5) administration. Table C shows the actual expenditures under these heads for each year since the foundation of the Institution.

C—Aggregate of expenditures

Year ending Oct. 31	Purchase of bonds	Large projects	Minor grants and pay- ments from Pension, Insurance, and General Contingent Funds	Publica- tions	Adminis- tration	Total
1902	.....	.....	\$4,500.00	.....	\$27,513.00	\$32,013.00
1903	\$100,475.00	.....	137,564.17	\$938.53	43,627.66	282,605.36
1904	196,159.72	\$49,848.46	217,383.73	11,590.82	36,967.15	511,949.88
1905	51,937.50	289,940.79	149,843.55	21,822.97	37,208.92	530,753.73
1906	63,015.09	381,972.37	93,176.26	42,431.19	42,621.89	623,216.80
1907	2,000.00	500,548.58	90,176.14	63,804.42	46,005.25	702,534.39
1908	68,209.80	448,404.65	61,282.11	49,991.55	48,274.90	676,163.01
1909	116,756.26	495,021.30	70,813.69	41,577.48	45,292.21	769,460.94
1910	57,889.15	427,941.40	83,464.63	49,067.00	44,011.61	662,373.79
1911	51,921.79	454,609.75	72,048.80	37,580.17	45,455.80	661,616.31
1912	436,276.03	519,673.94	103,241.73	44,054.80	43,791.13	1,147,037.63
1913	666,428.03	698,337.03	110,083.06	53,171.59	43,552.89	1,571,572.60
1914	861,864.23	817,894.52	107,507.55	44,670.55	44,159.54	1,876,096.39
1915	206,203.21	770,488.58	109,569.37	46,698.56	48,224.04	1,181,183.76
1916	473,702.70	638,281.41	99,401.26	73,733.38	49,454.08	1,334,572.83
1917	502,254.05	695,813.07	100,746.13	62,884.61	48,766.29	1,410,464.15
1918	528,565.55	693,780.00	170,470.74	44,394.83	49,118.76	1,486,329.88
1919	438,960.29	845,123.82	203,810.84	68,964.23	55,742.83	1,612,602.01
1920	464,279.57	876,437.28	159,633.49	95,933.10	68,739.90	1,665,023.34
1921	109,390.25	981,186.46	171,895.22	81,388.33	58,730.11	1,402,590.37
1922	50,431.05	975,149.20	192,325.46	96,227.01	56,405.15	1,370,537.87
1923	1,715,537.72	930,395.95	232,344.69	89,402.06	63,493.46	3,031,173.88
1924	440,921.24	939,739.67	230,291.90	87,790.74	65,076.47	1,763,820.02
1925	861,583.20	979,615.36	225,307.45	103,531.67	67,266.71	2,237,304.39
1926	178,817.80	1,060,525.36	254,977.20	84,526.23	65,871.48	1,644,718.07
1927	1,623,071.17	1,164,136.05	258,709.17	85,221.42	67,283.11	3,198,430.92
1928	26,010,438.19	1,208,942.20	281,308.76	93,571.02	73,052.60	27,667,312.77
1929	6,428,356.99	1,341,868.84	324,121.39	95,164.52	69,549.41	8,259,061.15
Total	42,705,445.58	19,165,676.04	4,315,998.49	1,670,132.78	1,455,256.35	69,312,509.24

CARNEGIE INSTITUTION OF WASHINGTON

On account of site for and construction of the Administration Building of the Institution, and on account of real estate, buildings and equipment of departmental establishments, the following sums have been expended since the foundation of the Institution:

Investments in Property

D—Real Estate and Equipment, Original Cost

Administration (October 31, 1929):		
Building, site and equipment.....		\$341,858.22
Division of Plant Biology (September 30, 1929):		
Buildings and grounds.....	\$123,761.54	
Laboratory	44,105.96	
Library.....	16,672.21	
Operating appliances.....	16,329.21	
		200,868.92
Department of Embryology (September 30, 1929):		
Library.....	2,301.01	
Laboratory	10,468.01	
Administration.....	6,033.48	
		18,802.50
Department of Genetics (September 30, 1929):		
Buildings, grounds, field.....	283,368.84	
Operating	22,992.46	
Laboratory apparatus.....	16,010.64	
Library.....	31,815.35	
Archives.....	45,488.90	
		399,676.19
Geophysical Laboratory (September 30, 1929):		
Building, library, operating appliances.....	203,903.48	
Laboratory apparatus.....	122,644.03	
Shop equipment.....	13,986.65	
		340,534.16
Department of Historical Research (September 30, 1929):		
Office.....	3,790.06	
Library.....	5,510.35	
		9,300.41
Tortugas Laboratory (September 30, 1922):		
Vessels	30,930.43	
Buildings, docks, furniture and library.....	12,130.86	
Apparatus and instruments.....	9,322.55	
		52,383.84

REPORT OF THE PRESIDENT, 1930

Department of Meridian Astrometry (September 30, 1929):

Apparatus and instruments.....	3,746.84	
Operating	4,809.15	
	<hr/>	\$8,555.99

Nutrition Laboratory (September 30, 1929):

Building, office and shop.....	128,231.04	
Laboratory apparatus	32,186.12	
	<hr/>	160,417.16

Mount Wilson Observatory (August 31, 1929):

Buildings, grounds, road and telephone lines.....	199,324.64	
Shop equipment.....	45,202.09	
Instruments	604,997.12	
Furniture and operating appliances.....	186,041.53	
Hooker 100-inch reflector.....	600,159.86	
	<hr/>	1,635,725.24

Department of Terrestrial Magnetism (September 30, 1929):

Building, site and office.....	212,164.47	
Vessel and survey equipment.....	222,698.98	
Instruments, laboratory and shop equipment....	145,228.71	
	<hr/>	580,092.16
		3,748,214.79

CARNEGIE INSTITUTION OF WASHINGTON

PUBLICATIONS

Sales of Publications and Value of those on Hand Table E shows the amounts received from subscriptions to the Index Medicus, from sales of Year Books, and from sales of all other publications for each year since the foundation of the Institution.

E—Table showing sales of publications

Year.	Index Medicus.	Year Book	Miscellaneous books.
1903.....	\$2,256.91	\$29.25	.....
1904.....	2,370.47	52.85	\$12.75
1905.....	2,562.76	44.75	431.44
1906.....	2,970.56	37.60	1,341.52
1907.....	3,676.71	56.50	2,292.89
1908.....	3,406.19	99.65	4,371.67
1909.....	4,821.85	73.01	6,287.21
1910.....	4,470.50	100.70	5,899.05
1911.....	4,440.21	85.50	6,366.55
1912.....	4,652.14	61.65	6,782.34
1913.....	4,992.02	75.95	7,140.69
1914.....	5,079.16	49.65	6,273.59
1915.....	5,010.21	47.60	5,239.98
1916.....	4,382.19	46.60	8,115.37
1917.....	4,616.21	51.55	7,253.59
1918.....	4,324.29	21.10	5,575.61
1919.....	4,267.95	93.30	8,476.33
1920.....	5,451.86	40.50	12,901.43
1921.....	6,277.32	50.55	10,356.64
1922.....	5,774.59	59.25	8,248.00
1923.....	5,777.46	70.10	7,994.20
1924.....	4,533.68	31.00	7,429.53
1925.....	5,636.25	25.00	8,019.49
1926.....	5,728.31	41.40	8,269.31
1927.....	1,650.65	59.67	8,322.10
1928.....	887.85	87.80	9,948.60
1929.....	433.70	41.74	8,450.47
Total.....	110,452.00	1,534.22	171,800.35

At the end of the fiscal year there are on hand 89,438 volumes of miscellaneous publications and Year Books, having a sale value of \$258,782.80, also 1,513 complete volumes of the Index Medicus which together with miscellaneous numbers have a value of \$15,443.75.

REPORT OF THE PRESIDENT, 1929

Growth and Ex- The data furnished in table F are of statistical
tent of Institu- interest in respect to the work of publication of the
tion's Publica- Institution. 585 volumes, which embrace a total
tions of 171,515 pages of printed matter, have thus far been issued.

F—Statistics of publications

Year	Number of volumes issued	Number of octavo pages	Number of quarto pages	Total number of pages
1902.....	3	46	.....	46
1903.....	3	1,667	.....	1,667
1904.....	11	2,843	34	2,877
1905.....	21	3,783	1,445	5,228
1906.....	19	3,166	1,288	4,454
1907.....	38	6,284	3,428	9,712
1908.....	28	4,843	2,485	7,328
1909.....	19	3,695	1,212	4,907
1910.....	29	3,274	4,831	8,105
1911.....	30	5,062	1,670	6,732
1912.....	23	3,981	2,044	6,025
1913.....	29	6,605	2,752	9,357
1914.....	23	4,978	1,934	6,912
1915.....	23	4,686	1,466	6,152
1916.....	35	9,478	2,430	11,908
1917.....	21	4,464	2,691	7,155
1918.....	17	3,073	1,120	4,193
1919.....	29	5,834	2,431	8,265
1920.....	23	3,962	3,710	7,672
1921.....	18	4,068	1,398	5,466
1922.....	24	4,566	2,039	6,605
1923.....	20	6,459	604	7,063
1924.....	17	4,665	834	5,499
1925.....	24	3,970	1,277	5,247
1926.....	14	4,552	850	5,402
1927.....	17	4,520	2,089	8,609
1928.....	15	4,495	1,044	5,539
1929.....	12	4,938	452	5,390
Total...	585	123,957	47,558	171,515

CARNEGIE INSTITUTION OF WASHINGTON

The publication of 13 volumes has been authorized by the Executive Committee during the year, at an aggregate estimated cost of \$85,250. The following list gives the titles and names of authors of the publications issued; it includes 12 volumes, with an aggregate of 4,938 octavo pages and 452 quarto pages. Nine additional volumes are now in press.

LIST OF PUBLICATIONS ISSUED BY CARNEGIE INSTITUTION OF WASHINGTON DURING THE YEAR ENDING OCTOBER 31, 1929

- Year Book, No. 27, 1927-1928. Octavo, xix-49-438 pages, 2 pls., 13 figs.
- No. 254. Vol. III. Davenport, Frances G. European Treaties bearing on the History of the United States and its Dependencies, 1650 to 1697. Octavo, vi+386 pages.
- No. 371. Vol. IV. Bassett, John S. Correspondence of Andrew Jackson. Octavo, xxii+508 pages.
- No. 374. Vol. II. Catterall, Helen T. Judicial Cases concerning American Slavery and the Negro. Octavo, x+661 pages.
- No. 382. Willis, Bailey. Studies in Comparative Seismology: Earthquake Conditions in Chile. Quarto, xi+178 pages, 75 pls., 19 figs.
- No. 385. Woodring, Wendell P. Contributions to the Geology and Palæontology of the West Indies. Miocene Mollusks from Bowden, Jamaica. Part II: Gastropods and Discussion of Results. Octavo, vii+564 pages, 40 pls., 3 figs.
- No. 390. Vol. I. Hay, Oliver P. Second Bibliography and Catalogue of the Fossil Vertebrata of North America. Octavo, viii+916 pages.
- No. 394. Contributions to Embryology, Vol. XX. Nos. 109 to 117. Quarto, vi+257 pages, 52 pls., 33 text-figs.

This book contains the following papers:

- Heuser, C. H., and G. L. Streeter.—Early Stages in the Development of Pig Embryos, from the Period of Initial Cell Cleavage to the Time of the Appearance of Limb Buds. (Contribution No. 109.)
- Flexner, L. B.—The Development of the Meninges in Amphibia: a Study of Normal and Experimental Animals. (Contribution No. 110.)
- Wislocki, George B.—On the Placentation of Primates, with a Consideration of the Phylogeny of the Placenta. (Contribution No. 111.)
- Corner, G. W.—A Well-Preserved Human Embryo of 10 Somites. (Contribution No. 112.)
- Cummins, H.—The Topographic History of the Volar Pads (walking pads: Tastballen) in the Human Embryo. (Contribution No. 113.)
- Langworthy, O. R.—A Correlated Study of the Development of Reflex Activity in Fetal and Young Kittens and the Myelination of Tracts in the Nervous System. (Contribution No. 114.)

REPORT OF THE PRESIDENT, 1929

Lewis, W. H.—The Effect of Various Solutions and Salts upon the Pulsation Rate of Isolated Hearts from Young Chick Embryos. (Contribution No. 115.)

Lewis, W. H.—Macrophages and Other Cells of the Deep Fascia of the Thigh of the Rat. (Contribution No. 116.)

Schultz, A. H.—The Technique of Measuring the Outer Body of Human Fetuses and of Primates in General. (Contribution No. 117.)

No. 395. Davenport, Charles B., and Morris Steggerda. Race Crossing in Jamaica. Octavo, ix+516 pages, 29 pls., 168 figs.

No. 397. MacDougal, D. T., J. B. Overton, and Gilbert M. Smith. The Hydrostatic Pneumatic System of Certain Trees: Movements of Liquids and Gases, Octavo, 99 pages, 22 text-figs.

No. 398. Clements, Frederic E., John E. Weaver, and Herbert C. Hanson. Plant Competition: Analysis of Community Function. Octavo, xvi+340 pages, 32 pls., 30 figs.

No. 399. Morgan, T. H., A. H. Sturtevant, C. B. Bridges, Ju Chi Li, and L. V. Morgan. Contributions to the Genetics of *Drosophila melanogaster* and *Drosophila simulans*. Octavo, vi+296 pages, 18 figs.

This book contains the following papers:

I. Sturtevant, A. H.—The Genetics of *Drosophila simulans*.

II. Bridges, C. B.—Variations in Crossing Over in Relation to Age of Female in *Drosophila melanogaster*.

III. Ju Chi Li and C. B. Bridges.—Deficient Regions of Notches in *Drosophila melanogaster*.

IV. Morgan, T. H.—Exceptional Sex-Ratios in Certain Mutant Stocks with Attached X's.

V. Morgan, T. H.—The Variability of Eyeless.

VI. Morgan, T. H.—Data relating to Six Mutants of *Drosophila*.

VII. Morgan, T. H.—Experiments with *Drosophila*.

VIII. Morgan, L. V.—Composites of *Drosophila melanogaster*.

No. 403. Contributions to Archæology from Carnegie Institution of Washington. Quarto, 27 pages, 25 pls., 3 figs.

Of this volume the following paper has appeared:

I. Ricketson, Oliver jr.—The Excavations at Baking Pot, British Honduras, 1924.

No. 404 Contributions to Palæontology from Carnegie Institution of Washington. Octavo.

Of this volume the following papers have appeared:

I. Buwalda, John P., and Bernard N. Moore.—The Dalles and Hood River Formations, and the Columbia River Gorge.

II. Buwalda, John P.—A Neocene Erosion Surface in Central Oregon.

MISCELLANEOUS

Reports of the Conferences on Cycles.

Factor Stencils. By Derrick Norman Lehmer.

Illustrated Pamphlet, descriptive of the work of the Carnegie Institution of Washington. Octavo, 63 pages, 27 figs.

CARNEGIE INSTITUTION OF WASHINGTON

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REPORT OF THE EXECUTIVE COMMITTEE

REPORT OF THE EXECUTIVE COMMITTEE

To the Trustees of the Carnegie Institution of Washington:

GENTLEMEN: Article V, Section 3, of the By-Laws provides that the Executive Committee shall submit, at the annual meeting of the Board of Trustees, a report for publication; and Article VI, Section 3, provides that the Executive Committee shall also submit, at the same time, a full statement of the finances and work of the Institution and a detailed estimate of expenditures for the succeeding year. In accordance with these provisions, the Executive Committee herewith respectfully submits its report for the fiscal year ending October 31, 1929.

During this year the Executive Committee held seven meetings, printed reports of which have been mailed to each Trustee, and are referred to as a part of this report.

Upon adjournment of the meeting of the Board of Trustees of December 14, 1928, the members of the Executive Committee met and organized by the election of Mr. Root as Chairman for 1929, and of Mr. Pritchett as Vice-Chairman for 1929.

A full statement of the finances and work of the Institution is contained in the report of the President, which has been considered and approved by the Executive Committee, and is submitted herewith. A detailed estimate of expenditures for the succeeding year is also contained in the report of the President, and has been considered by the Executive Committee, which has approved the recommendations of the President in respect thereto and has provisionally approved the budget estimates based thereon and submitted herewith.

The Board of Trustees, at its meeting of December 14, 1928, appointed Messrs. F. W. Lafrentz & Company to audit the accounts of the Institution for the fiscal year ending October 31, 1929. The report of the Auditor, including a balance-sheet showing assets and liabilities of the Institution on October 31, 1929, is submitted as a part of the report of the Executive Committee.

There is also submitted a statement of receipts and disbursements since the organization of the Institution on January 28, 1902.

Three vacancies exist in the membership of the Board of Trustees, caused by the resignation of Martin A. Ryerson, submitted at the annual meeting of the Board on December 14, 1928; by the death of Myron T. Herrick on March 31, 1929; and by the death of William W. Morrow on July 24, 1929. Nominations for such vacancies have been requested, in accordance with

CARNEGIE INSTITUTION OF WASHINGTON

provisions of the By-Laws, and such nominations will be submitted to the Board of Trustees at its annual meeting on December 13, 1929.

Tenure of office of John J. Carty and of George W. Wickersham as members of the Executive Committee terminates at the coming annual meeting.

ELIHU ROOT, *Chairman*
JOHN J. CARTY
W. CAMERON FORBES
JOHN C. MERRIAM
WM. BARCLAY PARSONS
STEWART PATON
HENRY S. PRITCHETT
GEORGE W. WICKERSHAM

November 18, 1929.

Aggregate Receipts and Disbursements From Organization, January 28, 1902, to Oct. 31, 1929

RECEIPTS		DISBURSEMENTS	
<i>Interest</i>		<i>Investment</i>	(a)
Endowment.....	\$26,496,368.08		\$42,705,445.58
Reserve Fund.....	1,991,321.99		
Colburn Fund.....	68,962.52	<i>Pension Fund</i>	358,079.62
Harriman Fund.....	118,000.		
Pension Fund.....	87,291.49		
Insurance Fund.....	245,601.92	<i>Insurance Fund</i>	45,445.89
Sp'l. Emer. Reserve Fund.....	7,917.99		
	\$29,015,403.99		
<i>Colburn Fund</i>		<i>General Contingent Fund</i>	45,817.03
	52,015.74		
<i>Sales of Publications</i>		<i>Sp'l. Emer. Reserve Fund</i>	63,511.79
	283,786.57		
<i>Reversions</i>		<i>Grants</i>	
	452,570.69	Large.....	\$19,165,676.04
		Minor.....	3,653,069.16
<i>Pension Fund</i>	28,324.07		
		<i>Publication</i>	1,670,132.78
<i>Redemption and Sale of Bonds</i>	34,942,359.12		
		<i>National Research Council</i>	150,000.
<i>Carnegie Corp'n of N. Y.</i>	4,794,791.67		
		<i>Administration</i>	1,455,331.35
<i>Miscellaneous</i>			
Sale of paper.....	6,684.96		69,312,509.24
Insurance.....	6,938.12	<i>Cash in Banks</i>	270,425.69
	13,623.08		
	69,582,934.93		69,582,934.93

(a) Including Administration Building, \$300,915.69, and Collection Charges.

REPORT OF AUDITORS

Washington, D. C., *November 29, 1929.*

TO THE BOARD OF TRUSTEES,
*Carnegie Institution of Washington,
Washington, D. C.*

DEAR SIRs:

We have audited the books and accounts of the Carnegie Institution of Washington for the fiscal year ended October 31, 1929. The books of the various departments are audited by the Bursar and Assistant Bursar. We have included their figures in the balance sheet without examination by us.

The income from investments and other sources has been accounted for and disbursements were supported by vouchers.

We counted the cash on hand, and the cash in banks was confirmed by certificates from the depositaries.

The securities representing the investments were examined by us.

We certify that the balance sheet, the schedules of securities and real estate and equipment, and the statement of receipts and disbursements as shown in the regular printed financial statement of the Institution at the close of business October 31, 1929, are in accordance with the books, and in our opinion the balance sheet fairly states the financial condition of the Institution at that date.

Respectfully submitted,

F. W. LAFRENTZ & CO.,
Certified Public Accountants.

Copies of the Financial Statement, certified
by the auditor in the above report, on pages
100 to 105.

Balance Sheet, October 31, 1929

100

Receipts and Disbursements for Year Ending Oct. 31, 1929

101

CARNEGIE INSTITUTION OF WASHINGTON

Schedule of Securities

Par Value Represented in Thousands							Aggregate— Par or Nominal Value	Description	Mat- ur- ity	Int. Due	Total Cost or Value at Date Acquired
Endow- ment	Col- burn	Harri- man	Re- serve	In- sur- ance	Pen- sion	Spl. Em. Re. Fd.					
\$500							\$500,000	<i>Railways</i> A. T. & S. Fe. 1st & ref. 4½s.....	1962	M-S	\$498,750.
43							43,000	" " conv. 4s.....	1955	J-D	39,022.50
				\$50			50,000	A. T. and S. Fe. gen. 4s.....	1995	A-O	50,056.25
50			\$100				150,000	B. and O.R.R. gen. and ref. 5s.....	1995	J-D	153,625.
200							200,000	Boston & Maine 1st 5s.....	1967	M-S	195,812.50
100							100,000	Canadian National Ry. Co. 5s.....	1969	J-J	98,500.
100							100,000	Canadian Pac. Col. Trust 4½s.....	1946	M-S	98,125.
			40		\$10		50,000	Canada So. con. 5s.....	1962	A-O	49,021.50
175							175,000	Ches. & Ohio gen. 4½s.....	1992	M-S	174,062.50
25							25,000	Ches. & Ohio Ry. ref. and imp. 4½s.....	1993	A-O	23,500.
100							100,000	Ches. & O.R.R., Eq. Tr., Series 1929.....		M-N	98,825.50
			50				50,000	Cent. Pac. Ry. 1st ref. 4s.....	1949	F-A	48,250.
			150	30			180,000	C. B. & Q. R. R. gen. 4s.....	1958	M-S	169,501.25
		\$200					200,000	C. B. and Q. Ill. Div. 4s.....	1949	J-J	200,000.
35							35,000	C. M. St. P. & P. 5s.....	1975	F-A	31,853.50
199							189,000	Chi., Ind. & L. 1st & gen. 5s.....	1966	M-N	189,461.25
140							140,000	Chi. M. St. P. & P. conv. adj. 5s.....	2000	A-	127,414.50
214	\$4		15	1			234,000	C. M. and St. P. Ry. gen. 4½s.....	1989	J-J	227,162.50
			120				120,000	Chi. and N. W. Ry. gen. 3½s.....	1987	FMAN	100,300.
200							200,000	Chi. & N. W. R. R. gen. 4½s.....	1987	M-N	210,000.
300							300,000	Chi. R. I. & P. Ry. 4½s.....	1952	M-S	282,362.50
25			75				100,000	Chi. U. Station 6½s.....	1963	J-J	114,266.50
100							100,000	Clev. C.C. & St. L. Ry. ref. and imp 4½s.....	1977	J-J	99,272.50
25	10		5		10		50,000	Clev. U. Term. 1st sink. 5½s.....	1972	A-O	51,612.50
50							50,000	Col. & Sou. Ry. ref. & ext. 4½s.....	1935	M-N	48,000.
375							375,000	Elgin J. & E. Ry. Eq. 5s.....		J-J	375,000.
360							360,000	" " " 6s.....		A-O	360,000.
300							300,000	Erie R. R. gen. 4s.....	1996	J-J	242,937.50
			48	21			69,000	Gt. Nor. 1st ref. 4½s.....	1961	J-J	69,058.25
125							125,000	Gt. Nor. Ry. gen. 4½s.....	1977	J-J	122,656.25
165							165,000	" " " 5s.....	1973	J-J	174,712.50
300							300,000	Ill. Cent. R. R. Joint 5s.....	1963	J-D	311,291.50
			100	21			121,000	Ill. Cent. R. R. ref. 4s.....	1955	M-N	109,677.50
220							220,000	Ill. Cent. Eq. Trust, 4½s.....		A-O	211,687.79
350			50				400,000	Kan. City Term. 1st 4s.....	1960	J-J	359,457.50
200							200,000	Kan. City, F. S. & M. Ry. ref. 4s.....	1936	A-O	187,250.
325							325,000	Lehigh and L. E. 4½s.....	1957	M-S	331,568.30
100							100,000	Lehigh V. H. Term. Ry. 1st 5s.....	1954	F-A	104,750.
			50				50,000	Long Island ref. 4s.....	1919	M-S	48,285.
150							150,000	Louisville & N.R.R. 1st & ref. 4½s.....	2003	A-O	150,000.
100			50	25	25		200,000	Mo. Kan. & T. 1st 4s.....	1990	J-D	165,206.26
150			15	25		\$23	213,000	Mo. Pac. R.R. Co. 1st and ref 5s.....	1977	M-S	212,762.50
200							200,000	Mo. Pac. R.R., Eq. Trust 4½s.....		M-N	192,206.79
150							150,000	Mobile and O.R.R., ref. and imp 4½s.....	1977	M-S	145,750.
175							175,000	N. Y. Cent. R.R. ref. & imp. 5s.....	2013	A-O	186,906.25
			50				50,000	N. Y. W. and Boston 1st 4½s.....	1946	J-J	49,187.50
70							70,000	Norfolk & W. Joint 4s.....	1941	J-D	64,925.
			95	5			100,000	Nor. Pac. ref. and imp. 6s.....	2047	J-J	102,187.50
			50				50,000	" " gen. lien 3s.....	2047	FMAN	33,101.25
	4		2	25	20		51,000	Ore. Short Line con. 5s.....	1946	J-J	49,883.25
200	10		50	25	25		310,000	Ore. Wash. R. & N. 1st ref. 4s.....	1961	J-J	274,272.50
	50		30				80,000	Pa. R. R. Co. gen. 4½s.....	1965	J-D	80,900.
			101	24			125,000	" " con. 4½s.....	1960	F-A	130,703.13
100							100,000	Pitta. C. C. & St. L. 5s.....	1975	A-O	99,637.50
	42						42,000	Pitta. Shawmut & Nor. 4s.....	1952		4,200.
			100				100,000	So. Pac. 1st ref. 4s.....	1955	J-J	92,148.75
		100					2100,000	So. Pac. S. F. Ter. 4s.....	1950	A-O	100,000.
200							200,000	So. Pac., con. 4½s.....	1969	M-N	180,000.
275			50	25			350,000	So. Rwy. Co. 1st con. 5s.....	1994	J-J	362,531.25
45							45,000	St. Paul Union D. 1st & ref. 5s.....	1972	J-J	48,150.
200					25		225,000	St. Louis-S. F., prior lien 4s.....	1950	J-J	203,431.25
130							130,000	Term. R. R. Assn. 4s.....	1953	J-J	114,609.25
210							210,000	Texas & Pac. R.P., gen. and ref. 5s.....	1977		213,882.50
2,084							2,084,000	Union R.R., deb. 6s.....	1946	J-D	2,084,000.
			140				140,000	Union Pac. 1st lien and ref. 4s.....	2008	M-S	128,722.50
150							150,000	Union Pac. R. R. 4s.....	1968	J-D	133,031.25
200							200,000	Va. Ry. Co. 1st 5s.....	1962	M-N	206,535.50
200							200,000	Wabash Ry., ref. and gen 6s.....	1976	F-A	203,250.
200							200,000	Western Md. R. R. 1st 4s.....	1952	A-O	162,100.
62							62,000	Wash Term. Co. 1st 3½s.....	1945	F-A	53,728.75
10,642	120	300	1,536	277	90	48	13,013,000	Railway Sub-Total.....			12,612,035.27

REPORT OF AUDITORS

Schedule of Securities—Continued

Par Value Represented in Thousands							Aggregate Par or Nominal Value	Description	Mat- urity	Int. Due	Total Cost or Value at Date Acquired
Endow- ment	Col- burn	Harri- man	Re- serve	In- sur- ance	Pen- sion	Spl. Em. Re. Fd					
								<i>Public Utility</i>			
\$150			\$50				\$200,000	Ala. Power Co. 1st ref. 5s	1951	J-D	\$197,250.
100							100,000	Ala. Power Co. 1st & ref. 5s	1968	M-S	99,656.25
125			47	\$53	\$25		250,000	Am. Tel. & Tel. sink, deb. 5½s	1943	M-N	260,521.25
300							300,000	Am. Tel. & Tel. deb. 5s	1960	J-J	308,000.
300							300,000	Apl. E. P. Co. 1st ref. 5s	1956	M-N	296,125.
250			50				300,000	Ark. P. & L. Co. 5s	1956	A-O	292,312.50
250							250,000	Bell Tel. Co. of Canada 1st 5s	1955	M-S	257,656.25
100							100,000	" " " " " "	1957	J-D	101,125.
300							300,000	Birmingham E. Co., 1st ref 4½s	1968	M-S	283,056.25
300							300,000	Car. P. & L. Co. ref. 5s	1956	A-O	302,298.75
185			25				210,000	Cedar R. Mfg. & P. Co. 1st sink 5s	1953	J-J	209,107.04
300							300,000	Cin. Gas. & E. 1st 4s	1968	A-O	268,105.75
300							300,000	Col. Gas. and Elec. deb. 5s	1952	M-N	303,125.
300							300,000	Columbus Rwy., P. & L. 4½s	1957	J-J	285,862.50
40							40,000	Comm. Edison 1st coll. 5s	1954	J-D	42,000.
115							115,000	" " " " " " 4½s	1956	A-O	114,193.75
65							65,000	Cons. P. Co. 1st 5s	1952	M-N	67,450.
			25	25			50,000	Consumers P. Co. 1st ref. 5s	1936	J-J	47,691.
			100				100,000	Detroit Edison gen. ref. 5s	1955	J-D	99,942.50
150							150,000	Detroit Edison gen. ref. 5s	1962	F-A	155,825.
300						\$25	325,000	Ga. Power Co. 1st ref. 5s	1967	M-S	320,112.50
300							300,000	Gatineau Power, 1st 5s	1956	J-D	298,750.
100							100,000	Gulf States Util. Co. 1st 5s	1956	M-S	94,537.50
100							100,000	Idaho P. Co. 5s	1947	J-J	100,750.
200							200,000	Illinois P. & L. 1st & ref. 5s	1956	J-D	196,750.
200							200,000	Indianapolis P. & L. 1st 5s	1957	J-J	198,806.25
200							200,000	Ind. & Mich. Elec. Corp., 1st ref. 5s	1955	M-S	202,182.50
300							300,000	Inter. Tel. & Tel. deb. 4½s	1952	J-J	288,250.
			280				280,000	Int. Rap. Trans. ref. 5s	1966	J-J	276,701.
			27	25	20		72,000	Kan. City P. & L. 5s	1952	M-S	71,955.35
40							40,000	Louisville G. & L. 1st & ref. 5s	1952	M-N	41,368.75
300							300,000	Memphis P. & L. 1st & ref. 4½s	1978	A-O	279,250.
300							300,000	Milwaukee E. R. & L. ref. & 1st 5s	1961	J-D	302,337.50
100							100,000	Minna P. & L. 1st & ref. 4½s	1978	M-N	92,156.25
110							110,000	Narragansett E. Co. 1st 5s	1957	J-J	109,787.50
			30	12	10		52,000	N. Eng. Tel. & Tel. 5s	1952	J-D	51,748.
100							100,000	New Orleans Pub. S. 5s	1955	J-D	99,200.
			50				50,000	N. Y. Edison 1st ref. 6½s	1941	A-O	55,573.75
			18		24		42,000	N. Y. Gas. E. L. H. P. pur. mon. 4s	1949	F-A	34,620.50
300							300,000	New York P. & L., 1st 4½s	1967	A-O	286,125.
60							60,000	Niagara Falls P. 1st & con. 5s	1959	J-J	61,800.
300							300,000	No. Ind. Pub. S. 1st ref. 5s	1966	M-N	305,775.
185							185,000	Nor. States P. 1st ref. 5s	1941	A-O	184,690.75
300							300,000	Ohio Power Co., 1st and ref. 4½s	1956	J-D	280,181.25
200							200,000	Okla. G. & E. 1st 5s	1950	M-S	200,000.
150			50				200,000	Pac. G. & E. Co. gen. & ref. 5s	1942	J-J	197,185.53
25							25,000	Pac. Tel. & Tel. 5s	1952	M-N	26,187.50
50							50,000	Penn. P. L. 1st & ref. 5s	1952	A-O	51,250.
65							65,000	Penn. W. & P. 1st ref. 4½s	1968	M-S	63,212.50
100							100,000	Peoples G. L. & C. 1st & ref. 5s	1976	J-J	102,250.
425							425,000	Phila. E. Co. 1st & ref. 4½s	1967	M-N	427,106.25
100							100,000	Pub. Serv. of Nor. Ill. 1st & ref. 5s	1956	A-O	101,975.
150							150,000	" " E. & G. 1st & ref. 4½s	1967	J-D	150,375.
200							200,000	San Joaquin L. & P. Corp., ref. 5s	1957	J-J	201,968.75
300							300,000	Shawinigan W. & P. 1st & coll. 4½s	1967	A-O	286,212.50
			50				50,000	So. Bell Tel. & Tel. 1st sink. 5s	1941	J-J	47,687.50
300							300,000	So. Calif. Edison Co., ref. 5s	1952	M-S	307,457.50
			50				50,000	So. Calif. Tel. Co. 1st ref. sink. 5s	1947	M-N	46,000.
200							200,000	So. Pub. Util. Co. 5s	1943	J J	200,000.
100							100,000	Tenn. E. & P. 1st and ref. 5s	1956	J-D	100,912.50
250			50				300,000	Tex. P. & L. Co., ref. 5s	1956	M-N	306,067.50
175			20	25			230,000	Utah L. & T. Co., ref. 5s	1944	A-O	215,193.
250			50				300,000	Va. E. & P. Co. 1st and ref. 5s	1955	A-O	301,606.2
10,465			972	140	79	25	11,681,000	Public Utility Sub-Total			11,547,390.32

CARNEGIE INSTITUTION OF WASHINGTON

Schedule of Securities—Continued

Par Value Represented in Thousands							Aggregate— Par or Nominal Value	Description	Mat- urity	Int. Due	Total Cost or Value at Date Acquired
Endow- ment	Col- burn	Harri- man	Re- serve	In- sur- ance	Pen- sion	Spl. Em. Re. Fd.					
MORTGAGES											
\$100							\$100,000	1st Mtr. 1184 Cromwell Ave., N. Y. 5½%	1932	M-S	\$99,500.
100							100,000	1st Mtg. N.W. co. Westbury Ct. & Flatbush Ave., Brooklyn 5½%	1933	M-N	100,000.
100							100,000	Mtg.-Bond Co. of N. Y. 5s.	1933	J-D	96,000.
100							100,000	N. Y. T. & Mtg. Co. 1st 5½%	1933	J-J	100,000.
400							400,000				395,500.
Industrial											
200							200,000	Aluminum Co. of A. 1st sink deb 5s.	1952	M-S	201,070.12
			50				50,000	American Radiator Co. deb. 4½%	1947	M-N	49,125.
			38	50	25		113,000	Genl. Motors Acc. Corp. sink. 6s.	1937	F-A	113,093.75
200				40	35		275,000	Gulf Oil Corp., sink. deb. 5s.	1947	F-A	278,396.25
						15	15,000	Humble Oil & Ref Co., deb 5s.	1937	A-O	15,000.
40							40,000	Ind. Steel 1st 5s.	1952	M-N	41,400.
90							90,000	Lacka. Steel conv. 1st 5s.	1950	M-S	92,475.
			98		2		110,000	Liggett & Myers 7s.	1944	A-O	130,058.77
	10		95		5		110,000	Lorillard Co. 7s.	1944	A-O	128,614.75
94							94,000	Midvale S. & O. conv. 5s.	1936	M-S	94,205.
	8						8,000	Park & T. Co. sink. deb. 6s.	1936	J-D	6,400.
200							200,000	Rwy. Express Agency, 5s.		M-S	200,000.
275							275,000	Stand. Oil N. Y. deb. 4½%			264,398.31
2,129							2,129,000	Tenn. C. I., & R. Co. 5s.	1951	J-J	2,129,000.
10							10,000	Tex. Corp., Sinking deb. 5s.	1944	A-O	9,825.
200							200,000	Youngstown S. & Tube 1st S. 5s.	1978	J-J	200,850.
3,438	28		281	90	67	15	3,919,000	Industrial Sub-Total			3,953,911.95
Foreign											
189.5							189,500	German External Loan of 1924 7s.	1949	A-O	202,517.47
100							100,000	Govt. of Argentina 6s.	1960	M-N	98,250.
100							100,000	Imp. Japanese Govt. 6½%	1951	F-A	101,437.50
300							370,000	Kingdom of Denmark, ext. 4½%	1962	A-O	274,375.
			25				25,000	City of Montreal 5s.	1956	M-N	24,062.50
			75				75,000	City of Montreal sink 5s.	1954	M-N	72,375.
100							100,000	City of Montreal 4½%	1946	F-A	94,368.90
200							200,000	New South Wales, ext. 5s.	1958	A-O	189,562.50
100							100,000	Province of Alberta deb. 4½%	1958	J-J	93,750.
100							100,000	Province of Alberta 5s.	1950	A-O	110,125.
100							100,000	Province of British Col., 4½%	1951	J-J	98,675.
100							100,000	Province of British Col. deb. 5s.	1939	J-J	100,412.67
100							100,000	Province of British Col. deb. 5s.	1954	A-O	99,000.
200							200,000	Province of Manitoba deb. 4½%	1958	A-O	190,500.
			100				100,000	Province of Nova Scotia 4½%	1952	M-S	100,312.50
100							100,000	Province of Ontario 4s.	1964	M-N	87,150.10
25			35				60,000	Province of Ontario 5½%	1937	J-J	61,291.10
100							100,000	Province of Ontario 5s.	1959	M-N	99,750.
			40				40,000	Province of Ontario 6s.	1943	M-S	43,137.50
30							30,000	Prov. of Saskatchewan deb. 5s.	1943	J-D	30,627.44
75							75,000	Toronto Harbour Comm. 4½%	1953	M-S	72,062.50
			75	25			100,000	City of Toronto con. deb. 5s.	1949	J-D	96,152.42
90							90,000	City of Toronto, 5s.	1952	J-D	89,325.
			50				50,000	City of Winnipeg inter. deb. 5s.	1943	J-D	48,250.
			50				50,000	City of Winnipeg deb. 6s.	1946	A-O	53,500.
100							100,000	City of Winnipeg deb. 4½%	1946	J-D	95,375.
2,309.5			450	25			2,684,500	Foreign Sub-Total			2,617,545.10
Stocks											
50							50,000	A. T. & S. Fe. pref. stock		F-A	52,125.
200							200,000	Cons. Gas. Co. Cum. pref. stock		FMAN	198,725.
100							100,000	Du Pont de Nemours, deb. Stock			116,125.
50							50,000	J. I. Case Thresh. M. Co. Pfd. stock		JAJO	62,225.
40							40,000	Union Pac. R. R., pref. stock		A-O	33,415.
500							500,000	U. S. Steel Corp., pref. stock		FMAN	715,173.50
940							940,000	Stocks Sub-Total			1,177,788.50
28,094.5	148	300	3,239	532	236	88	32,637,500	Aggregate—Funds Invested			32,304,161.14

REPORT OF AUDITORS

Real Estate and Equipment, Original Cost

<i>Administration (October 31, 1929)</i>		
Building, site, and equipment.....		\$341,858.22
<i>Division of Plant Biology (September 30, 1929)</i>		
Buildings and grounds.....	\$123,761.54	
Laboratory.....	44,105.96	
Library.....	16,672.21	
Operating appliances.....	16,329.21	
		200,868.92
<i>Department of Embryology (September 30, 1929)</i>		
Library.....	2,301.01	
Laboratory.....	10,468.01	
Administration.....	6,033.48	
		18,802.50
<i>Department of Genetics (September 30, 1929)</i>		
Buildings, grounds, field.....	283,368.84	
Operating.....	22,992.46	
Laboratory apparatus.....	16,010.64	
Library.....	31,815.35	
Archives.....	45,488.90	
		*399,676.19
<i>Geophysical Laboratory (September 30, 1929)</i>		
Building, library, operating appliances.....	203,903.48	
Laboratory apparatus.....	122,644.03	
Shop equipment.....	13,986.65	
		340,534.16
<i>Department of Historical Research (September 30, 1929)</i>		
Office.....	3,790.06	
Library.....	5,510.35	
		9,300.41
<i>Tortugas Laboratory (September 30, 1929)</i>		
Vessels.....	30,930.43	
Buildings, docks, furniture, and library.....	12,130.86	
Apparatus and instruments.....	9,322.55	
		52,383.84
<i>Department of Meridian Astrometry (September 30, 1929)</i>		
Apparatus and instruments.....	3,746.84	
Operating.....	4,809.15	
		8,555.99
<i>Nutrition Laboratory (September 30, 1929)</i>		
Building, office, and shop.....	128,231.04	
Laboratory apparatus.....	32,186.12	
		160,417.16
<i>Mount Wilson Observatory (August 31, 1929)</i>		
Buildings, grounds, road, and telephone line.....	199,324.64	
Shop equipment.....	45,202.09	
Instruments.....	604,997.12	
Furniture and operating appliances.....	186,041.53	
Hooker 100-inch reflector.....	600,159.86	
		1,635,725.24
<i>Department of Terrestrial Magnetism (September 30, 1929)</i>		
Building, site, and office.....	212,164.47	
Vessel and survey equipment.....	222,698.98	
Instruments, laboratory, and shop equipment.....	145,228.71	
		580,092.16
		3,748,214.79

*Including Harriman Fund property in the amount of \$183,671.75 shown as a separate item on the Balance Sheet.

REPORTS ON INVESTIGATIONS

DEPARTMENT OF EMBRYOLOGY¹

GEORGE L. STREETER, DIRECTOR

Before describing the research activities of the Department, mention is to be made of the additional laboratory facilities placed at our disposal by the Johns Hopkins University. There had been distinct need of greater space for the accommodation of an increasing number of investigators and to provide for new requirements consequent upon the wider range over which our activities have been spreading. This need was met this past winter when we acquired the larger part of an additional floor of the New Hunterian Building, where, since its erection, our laboratory has been located. The new quarters were formerly occupied by the Medical School Library, and when the latter was removed to the William H. Welch Medical Library, the vacated space was generously allotted to us by the authorities of the University. It has been utilized for a general embryological study room, containing our whole collection of reconstruction-models and our embryological reprints, monographs, books and catalogues. In addition there is provided an artist's room and administration offices. Removing these to the first floor releases four rooms which are well adapted and equipped for laboratory purposes.

The researches with which this Department has been concerned and which have been completed during the past year are described in the following pages. Particularly outstanding is that of Dr. Lewis and Dr. Gregory in obtaining a cinematographic record of the developing mammalian egg. The importance of their work lies in the new approach it offers to the study of cell division. Just as the egg is too small to be studied with the naked eye and requires magnification, so the movements of its cytoplasmic elements are too slow to be seen directly and require visual speeding-up, in order to be detected. The Lewis-Gregory films do this for us and they reveal many unsuspected phenomena which throw light on the physical factors of cell division and the mechanism of the early organization of the ovum.

In brief summary, other investigations having a general embryological bearing include studies on the pig ovum, which in turn led to the study of the rabbit ovum and its cinematization, and observations on the rate of intra-uterine and postnatal development of the opossum. In the field of human embryology studies have been made of early stages, the female genital tract, and the formation of the cartilaginous skeleton and volar pads of the hand and foot. Progress is recorded in our studies on the pathology of the fetus, in particular, the problem of egg vitality and the nature of intra-uterine amputations. The technique of tissue culture has been applied to the study of allergy in tuberculosis, demonstrating that the individual cells of the allergic animal are hypersensitive to tuberculin. Observations have been made on endocardial cells. Tumor cells have been studied in the living state and new facts are recorded as to the properties of chicken-tumor virus. Further contributions have been made as to the distribution of macrophages and the histological character of deep fascia, also as to the nature of muscle contraction in the embryonic heart. Under investigations on the nervous system are included a re-examination of the Monro-Kellie hypothesis, the structure of the brain envelopes in amphibia, studies of the

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motor cortex and its electrical excitability, muscle tonus and a group of studies in which the development of the simpler reflex activities in fetal kittens and pouch-young opossums were correlated with the myelinization of the respective nerve fibers, providing basic principles upon which the understanding of the more primitive types of behavior must rest. In the field of reproduction there are included, in addition to observations on ovarian parasites and transplanted testes, a group of studies on the placenta of primates and of lower forms tending to show that the deciduate type of placenta is the more primitive, whereas, the diffuse placenta is an offshoot from it, adapted to highly specialized animals. Eighteen pregnancies in our monkey colony have made possible important observations on gestation, and in five cases very satisfactory motion picture records were obtained covering the various phases of parturition and the behavior of the newborn, which records can be studied in detail at our convenience. Equally important are the studies on uterine bleeding. It has been found that in addition to the typical periodic bleeding of menstruation, there is a second type associated with and diagnostic of pregnancy, and a third type, detectable only with the microscope, which is the homologue of the oestrous hemorrhage of such animals as the dog. The recognition of these three types removes some of the confusion that has made difficult an understanding of the significance of menstruation in man. In a final group there are reported various gross and microscopic studies on primates, marine mammals and sloths which by way of comparative anatomy contribute toward the understanding of structure, variation and function, as encountered in the human body.

GENERAL EMBRYOLOGY AND ORGANOGENESIS

It is evident that if we are to have specialization of tissues, such as is demanded in a highly complex organism like man, it can be accomplished only by a nice segregation of the diverse materials of which the various tissues are made. The possibility of segregation within the compass of an individual cell is quite limited and only suffices for the needs of primitive organisms where the growth range is small and the functional activities are simple. When larger and more complicated organisms are examined one finds that the necessary segregation and specialization has been made possible, in part at least, through cell division. Indeed, this participation in the phenomenon of segregation, including the preparatory events leading up to it, is to be regarded as an important, if not the most important, function of cell division, as it relates to the early ovum. It is to be noted that cell division is not merely a means toward increase in size through multiplication. We will see presently that the rabbit egg and the pig egg do not gain in size as the cells increase in number, but that the gain is correlated with the formation and growth of the segmentation cavity. In cell division we are dealing with something more than cell proliferation, and, carrying it further, a newborn baby is something more than a large tumor. In the development of the baby there has been segregation, differentiation, intricate histogenetic changes and a series of interactions of the resultant diverse tissues upon each other. If we are to understand how man acquires his present form, and the abnormalities that occasionally mar it, these various factors must be mastered. What we now know has come mostly through

experiment and observation on lower forms. During the past few years an approach to certain phases of this fundamental problem, as it affects the ovum in higher mammals, has been opened up in this laboratory. The studies are still in progress but certain definite advances that have already been made will here be briefly outlined.

THE PIG OVUM

For the study of cleavage and early differentiation of the mammalian embryo, the pig egg offers the advantages of being easily obtainable and simple in its organization. The segmentation cavity makes its appearance while the egg still consists of relatively few cells (16 to 32), making it possible to trace the cells responsible for its formation, and to trace the separation of the non-formative (implanting mechanism) from the formative (the embryo) elements of the ovum. No better embryo could be had for following the mesoderm and notochord in their uncomplicated origin. Finally in the later stages as organ systems are laid down, the embryo approaches the human conditions closely enough to make it a valuable supplement to our human material. Taking advantage of these circumstances Dr. C. H. Heuser and I, recently, have been studying this ovum. References to some phases of the work have appeared in my last two reports. During the past year a completed account of the study was published in the Contributions to Embryology. In this paper the successive steps in the development of the egg are traced from the one-cell stage to the time of the appearance of limb-buds. It includes a photographic record of the principal changes that terminate in a definitely organized embryo, reliably showing the morphological features of the closely overlapping developmental stages, this being the only adequate record we now have for a higher mammal.

THE RABBIT OVUM

The technique that had been developed in this laboratory in the handling, photographing and sectioning of pig eggs, was applied during the past year by Dr. P. W. Gregory to the study of the rabbit egg and his work is now being prepared for publication. Taking advantage of the living eggs, with which he was working, Dr. Gregory joined with Dr. W. H. Lewis in an effort to secure a cinematographic record of the process of segmentation. In this they were eminently successful and they have given us the first motion picture record of the dividing mammalian egg.

Briefly, their technique consists in cutting out the tubes of rabbits that have been mated so as to provide the desired ages, washing the eggs from the tubes with Locke solution, picking up five or six eggs of a litter with a small pipette and mounting each egg separately in rabbit blood plasma. The mount is made in a hanging drop on a glass slide, kept at body temperature. The egg selected for photography is placed on the microscope stage in a warm box under the cinematographic camera and exposures are made at the rate of two and one-half per minute at a magnification, on the film, of 44 diameters. Eggs under these conditions will live eight days. To be sure of the normal picture only the first 24 hours of the negative is utilized and by starting with eggs of different ages, which act as relays, one obtains a positive film from several eggs all of which is normal, that is, the appear-

ance of the egg remains like that of eggs of corresponding stage freshly removed from the tube.

Under these conditions the development was recorded from the first cell division, through successive cleavages and until the segmentation cavity is well established, covering that part of development that normally occurs in the tube and uterus between the end of the first day and the end of the fourth. Aside from the striking picture presented of cell division, there are many new things to be noted, such as the movements of the granules within the cells which are particularly active just before division, the shifting of cells after division, the pulsation of cells as a whole and changes in their size and in the size of the whole mass. Growth of the egg, however, begins with the formation of the segmentation cavity and progresses in proportion to the filling of the latter with fluid. In other words, cell division does not necessarily mean growth. Apparently the first cell division inaugurates the process of segregation. The first two blastomeres tend to be different in size and behavior. With further divisions one recognizes that the trophoblastic elements are being separated from the more retarded part of the egg, the inner cell mass, which is to form the embryo itself.

The possible period of culture of the egg is limited by the zona pellucida—the enveloping membrane which under normal conditions is softened or dissolved off. Under the above artificial conditions it persists as a resisting shell which with the expanding egg eventually ruptures. In so doing, a herniated monster is produced that can not longer be relied upon for the study of normal development. Before later stages can be grown some means must be devised for removing this obstacle.

RATE OF INTRA-UTERINE AND POSTNATAL DEVELOPMENT OF OPOSSUM

Experience indicates that the rate of development varies between different mammals and, in lesser extent, between individuals of the same species, or even of the same litter. Precise information on this subject, however, has been greatly needed. This uncertainty and our lack of data on the relation of oestrous and copulation to ovulation and the exact moment of fertilization of the ovum have made it impossible thus far to determine the true age of embryos. A definite contribution toward the solution of the first part of this problem has been made by Dr. C. G. Hartman. The procedure by which he determined rates of development consisted of removing, under aseptic surgery the left uterus of a selected animal and determining the stage of development of its contained ova. The animal was then allowed to live for a defined period of time when the remaining uterus was removed and the ova, which in the meantime had continued their development within it, were preserved for study. He thus had for each animal two or more lots of ova with a known duration of time between them. Planning his periods over the whole period of pregnancy he secured data that could be plotted on a chart covering the entire intra-uterine development. The first cleavage, in the opossum, requires about two and one-quarter days and the following cell divisions about one-quarter day each. The 1 mm. bilaminar blastocyst is found at six and one-half days. The whole period from coitus to parturition is about thirteen days. Of this time, seven and one-half days are

required to establish the germ disk with a primitive streak and beginning notochord. This leaves but five and one-half days in which the embryo is organized and brought to a developmental state capable of pouch life.

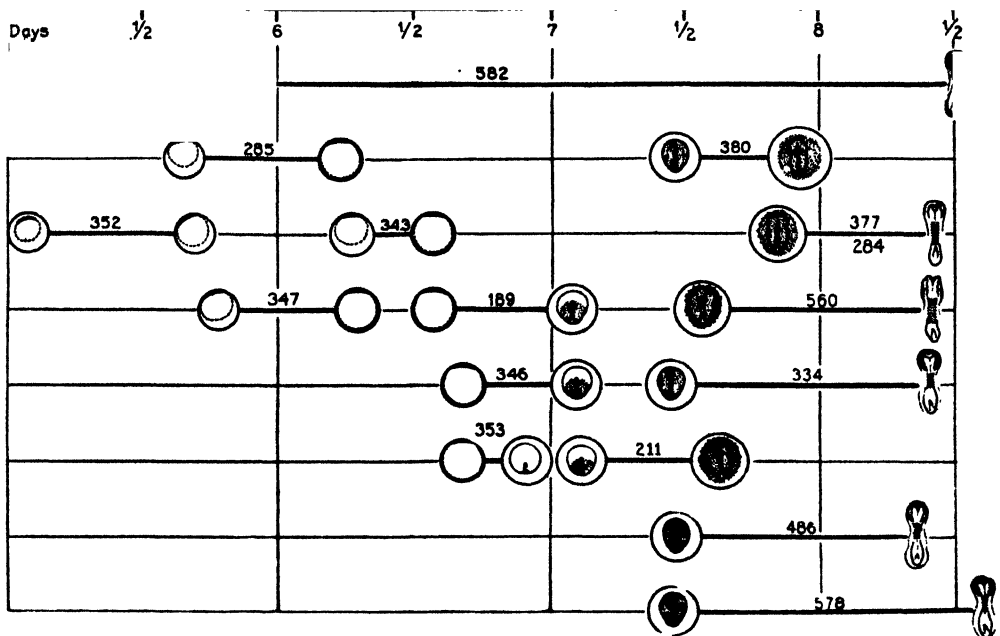


FIG. 1.—A portion of Dr. Hartman's chart showing rate of development of opossum embryo. Period covered is from five to eight and one-half days after coitus. In each instance two specimens were taken at different times from same mother.

Dr. Hartman also followed the postnatal growth covering such points as length, weight, appearance of hair, attachment to the teat, opening of eyes, weaning and independence. This with his previous studies completes a growth record of this important American marsupial that is hardly equalled in any other mammal. His paper includes valuable records regarding the breeding season.

HUMAN EMBRYO WITH TEN SOMITE-PAIRS

This laboratory is indebted to Dr. G. W. Corner, of the University of Rochester, for the opportunity of cooperating in the study of a very perfect human embryo falling in that important period of development when only the earlier somites are marked off and the chief organ systems are being laid down. The specimen was obtained under ideal conditions and it was possible to secure reliable photographic records of the external form of the embryo. Such photographs are of the utmost value for the interpretation of those faint markings that outline the primordia of the early embryonic structures. The histology of the sectioned embryo is unusually perfect and it is evident that the series has before it a career of service as a histological referee in the disputed points of the future, so far as this stage is concerned.

Basing his observations on the gross specimen, on graphic and three-dimensional reconstructions, and on microscopic study of the sections, Dr.

Corner has prepared a detailed description of the specimen which makes it available to all students of embryology. The treatment of the nervous system is particularly complete and includes a consideration of the question of segmentation of the brain stem and the demarcation of neuromeres. It is such studies as this that must provide the basis for the much needed improvement in our analysis of cerebral development. This embryo appears to be the youngest human specimen in which the pronephric rudiments can be satisfactorily recognized. A striking feature observed by him is a chromophilic granulation present in certain areas of the nervous system which appear to be of degenerative character. They are localized in the walls and floor of the fore-brain and in the torus opticus. That these occur in such a well-preserved embryo makes their consideration of particular importance.

CHONDRIFICATION OF THE HAND AND FOOT

For a number of years a program has been in effect in this laboratory leading toward the establishment of a series of stages of development of the human embryo, based on the external form. It was thought that such a guide would be more adequate than the crude system now in use, based on the length of the embryo. A new phase has been contributed to this program during the past winter by Dr. H. D. Senior, of New York University. He has shown that chondrification is a reliable guide to the relative stage of development of embryonic limbs. Previous studies on the hand and foot skeleton had been almost exclusively limited to ossification, which occurs relatively late. Chondrification makes it possible to work with earlier stages. Dr. Senior has studied 77 series of sectioned embryos, having a C. R. length ranging from 12.5 to 24.8 mm. From these he has been able to determine stages of development based on cartilage formation into which the hands and feet fit accurately. A preliminary account listing the order of chondrification has been published by him. A criterion based on cartilage, of course, can not be used in preliminary grading of specimens. Its value will be limited to sectional material or stained whole-mounts. On the other hand, many specimens have been already sectioned before the need of grading them arises.

VOLAR PADS IN THE HUMAN EMBRYO

Reference was made in my last report to the study of the volar pads by Dr. H. Cummins of Tulane University. Since then his work has been completed and appears in final form in the last volume of the Contributions to Embryology (Vol. XX). From his study of the surface markings of the hands and feet of human embryos and fetuses ranging from 17 mm. to 341 mm., sitting height, Dr. Cummins finds a significant correlation between pads and dermatoglyphs; in the period in which the pads are being lowered and their outlines are becoming less evident, the epidermal ridges become differentiated. From this concurrence the alignment of the epidermal ridges serves as a check and amplification of the results obtained by direct observation of the pads. From his observations it becomes certain that all embryos are initially provided with the full complement of primary pads. In the process of their involution, individual variations occur, both in the

longer persistence of definite pads in some fetuses, and in the forms and discreteness of the pads. The fact that they attain in the fetus great definiteness, followed by regression, and that the more primitive the pad, the better marked are its elevation and individuality, is suggestive of their recapitulatory nature. From this standpoint the final human pads are derived forms, lowered, merged with each other and into the common volar surface, some of them even being lost entirely.

DEVELOPMENT OF THE HUMAN FEMALE GENITAL TRACT

Through the generosity of the Rockefeller Foundation in the conduct of its fellowship plan, it was made possible for Dr. R. H. Hunter, of Queen's University, Belfast, to spend the past academic year with us and participate in our studies of the development of the utero-vaginal canal. Dr. Hunter devoted his attentions particularly to the cervical region during the little-known period of early fetal life. A preliminary account of his observations was read before the American Association of Anatomists and the completed study is now in course of preparation for publication. He has established the interesting fact that the fetal cervix goes through a series of growth changes similar to those described for the pregnant maternal cervix, and that the sudden reduction in length of the uterus at birth is due to a reduction in the length of the cervix rather than that of the body. This therefore constitutes a significant example of maternal hormonal influence on fetal growth. The formation of the cervix and body of the uterus is traced by Dr. Hunter to the canal formed by the fusion of the lower portions of the Mullerian ducts. The terminal portion of the fusion-canal becomes drawn out, loses its lumen and through the subsequent proliferation of its cells gives origin to the vaginal wall and the breaking down of its central cells, the vaginal lumen. The history of the female genital tract is thus gradually becoming better understood, and in consequence of such studies as Dr. Hunter's we may look forward to a better groundwork for the analysis of the normal and abnormal mechanisms of this important organ system.

PATHOLOGY OF THE FETUS

In the past it has been customary to attribute miscarriages in large part to endometritis, retroversion, faulty implantation, physical exertion and other environmental disturbances. It is now becoming evident that these factors play but a minor rôle. Seeing a large number of specimens, as we do in this laboratory, has taught us to recognize, with an increasing precision, the normal specimen from the abnormal and from the pathological. Furthermore, we are acquiring standards by which we can determine the length of time the dead fetus has been retained in the uterus, which of itself frequently rules out supposed causes, such as recent trauma. From such experience we have been forced, in a large proportion of the cases, to seek an explanation in the original constitution of the germ-plasm.

There has been demonstrated to exist throughout a great variety of plant and animal forms a wide variation in the degree of vitality of seeds and eggs. Among mammals that have plural births, particularly in those having large litters, it has been shown that from 20 to 30 per cent fail to develop properly and that the blame can only rest on the germ-plasm. The evidence

is accumulating that also in man the vitalities of the sperm and the ovum are factors of prime importance for normal development.

In studying these matters we have been fortunate in having the cooperation of Dr. J. L. Huntington, of Boston. During the past few years he has followed clinically 104 consecutive intra-uterine pregnancies that failed to reach the period of viability. The products of conception, in each instance, were examined at this laboratory, and the results have been carefully analyzed by him. He reaches the conclusion that defective germ-plasm is the chief cause of abortion and that it may occur in individuals that are otherwise essentially healthy; but the seriousness of such defect is increased by undernourishment, various toxications, focal infections and faulty endocrine functioning, both on the maternal and paternal sides. Dr. Huntington's study will enable the physician to deal more intelligently with cases of this kind. Even though the cause can not be removed there is much gained in knowing where it lies.

INTRA-UTERINE AMPUTATIONS

The type of defect referred to in the preceding paragraph involves the whole egg. The egg develops and lives in proportion to the vitality with which it is endowed. Good eggs produce hardy, long-lived individuals and poor eggs succumb during uterine life, infancy, or early years of maturity. In addition to this quality of the egg as a whole, account must be taken of the varying degrees of vitality of its different parts. In the human individual it is found that some structures succumb long before others. That this disparity in vitality of the different tissues is inherent in the germ-plasm is evidenced by the fact that these shorter lived parts are hereditarily transmitted—for example, the hair follicles of the scalp. There is a range within which the disparity may be regarded as normal. When it is beyond those limits we enter the domain of the abnormal and pathological. Accepting this viewpoint one should be prepared to meet in the fetus focal degenerations and arrests of development, of one sort or another, which are not to be directly attributed to infections or physical or chemical disturbances but to the fact that the original vitality of those parts was sufficient to carry them but part of the distance along their course of development, at which time they either remain stationary in whatever state they have attained, or break down and disappear. During the past few years I have been studying the problem of intra-uterine amputation and in some of its phases am led to regard it as due to focal defects of the tissues, that are to be interpreted in a way such as I have outlined.

Intra-uterine amputations are rare; among over 8,000 specimens in the Carnegie Collection there are but nine showing this defect. From a study of these there is no clear evidence that the process is due to amniotic bands. Structures that have frequently been described as amniotic bands apparently fall into two categories: (a) macerated sheets of epidermis; (b) strands of exuded fibrous tissue originating from localized necrotic areas of the superficial mesenchymal tissues.

The active stage of the phenomenon of amputation is found in the first half of pregnancy and consists primarily of sharply localized necrosis of the subcutaneous soft tissues. It either involves the ends of one or more digits

or is limited to an annular area partially or completely surrounding the respective extremity higher up. If enough tissue is involved, amputation ensues, and the stump heals by granulation. Where the process is more limited, a sharp crease is left corresponding to the destroyed area. The phenomenon is limited to the limb-bud tissues and tends to be symmetrical in the sense of involving all four extremities, although the parts affected are usually at different levels. This distribution is one that would be expected in a process that is germinal in origin and my study of these cases, which is now nearing completion, leads me to this interpretation.

STUDIES OF LIVING TISSUES

MACROPHAGES OF THE DEEP FASCIA

That monocytes (large mononuclears) and macrophages (clasmatoocytes) are merely different forms of the same cell, differing only in the amount and character of the ingested matter, as was originally shown by the stagnant blood-cultures of Mrs. Lewis, has been further confirmed by Dr. W. H. Lewis. He shows that the transformations demonstrated in blood cultures are normally occurring in the extravascular tissue spaces of the living animal. Mounting, in a modified Locke solution, with and without neutral red and janus green, thin spreads of deep fascia of the thigh muscles of the white rat he obtained preparations in which the various cells of the tissues could be studied and photographed while still living and in their natural environment. He was thus able to demonstrate that the macrophages of the subcutaneous tissues vary greatly in size, appearance and distribution. All stages from large mononuclear blood-cells to the large macrophages are always abundantly present. On the other hand, the fibroblasts, which are easily distinguished from the macrophages by their form and reaction to neutral red, exhibit no transitional stages that would indicate relationship to the macrophages. Among other distinct cell-types there are to be noted: numerous mast cells characterized by the vigorous affinity of their granules for neutral red and janus green; polymorphonuclear neutrophiles; and especially eosinophiles, of which there are present more than twenty-five times as many as in the circulating blood. One obtains a conception of the great prevalence of macrophages from Dr. Lewis' estimate that in the subcutaneous tissue of a 200-gram rat there are about 855,000,000 of them, which is several hundred times the combined number of mononuclears, transitionals and large lymphocytes of the circulating blood. The purpose of this rich peculiar equipment is a question of great interest. There is no doubt of its phagocytic and digestive nature and that it has to do with plasma and fibrin, rather than solid bodies and dead cells, would seem likely, as the latter do not seem to be normally present in tissue spaces. It is his suggestion that the macrophages may by ingestion and digestion convert the plasma and fibrin into a more soluble and diffusible state and thus are more readily carried off by the lymphatics and blood-vessels or utilized as food by other cells.

In the course of his study of these living spreads of deep fascia, Dr. Lewis has made numerous collateral observations that will be of especial interest to the histologist, such as: the absence of syncytial connections of

the fibroblasts; smooth-muscle cells of the blood-vessels; vascular endothelium and its reactions to neutral red; and the characteristics of the plasma and blood-cells within the blood-vessels as seen under this method of examination.

ALLERGY IN TUBERCULOSIS

An important contribution as to the nature of allergy (exaggerated specific susceptibility) in tuberculosis has been made during the past year by Dr. A. R. Rich and Mrs. M. R. Lewis in showing that under this condition there is a change in the individual cells that renders them more sensitive to the products of the tubercle bacillus. They made cultures of spleen and white-blood cells of guinea-pigs and demonstrated that those of an allergic animal are more sensitive to the effects of tuberculin than are those of a normal animal. Those of the allergic animal are killed by amounts of tuberculin in which normal cells grow freely. They further proved that the plasma has no part in it, for the sensitiveness of the washed cells of an allergic animal is just as great, regardless of whether they are exposed to tuberculin in the plasma of normal or of allergic animals. On the other hand, tuberculin in allergic plasma has no more effect upon normal cells than has tuberculin in normal plasma. To know that in the allergic body the isolated cells are changed in a manner which renders them more sensitive than normal cells to the products of the tubercle bacillus is a definite step in advance in our knowledge of the nature of this disease. It is only through tissue culture that sensitiveness of isolated body-cells could have been determined with adequate precision.

STUDIES ON TUMOR-CELLS

In order to test the susceptibility of tumor-tissue to heat and to determine the thermal death point of a given type of tumor-cell, Dr. H. B. Friedgood has utilized the tissue-culture technique with the Walker rat tumor No. 1 (spindle-cell sarcoma). The cultures were exposed to various degrees of heat over short periods and were subsequently tested by observing the growth of the culture. To secure greater accuracy than is provided by a warm air chamber the heat was administered by submersion of the sealed culture in a heated water bath for periods of 15 to 30 minutes, after which the culture was incubated at 38 C. for 48 hours and the resultant growth recorded. It was found that exposure of cultures of this particular tumor at 44 C. for 30 minutes incapacitates the cells for further growth. Dr. Friedgood found that there was no apparent difference in the relative susceptibility of the two kinds of cells that constitute the tumor (malignant cells and normal mononuclear cells). It now remains to make a similar test of various normal tissues and other tumors before one would be warranted in employing the principle as a therapeutic measure.

The pathologist has long sought, with indifferent success, criteria by which malignancy of cells might be recognized. The most constant characteristic appears to be an increased amount of nuclear material. During the past year Mrs. Lewis and Miss J. Lockwood have studied this particular feature in the Walker rat sarcoma. The Walker tumor contains two types of cells;

a small mononuclear blood-cell and a large spindle cell. The latter was found to have twice as much chromosome material during mitosis as the mononuclear cell. On counting the chromosomes these investigators found that the large spindle cell during division contained the tetraploid number of chromosomes (84), whereas the mononuclear cell contained the usual diploid number (42). An extensive study of these cells at metaphase, anaphase and after division, both in cultures and in sections of the sarcoma, showed that this chromosomal difference is constant. On the other hand, cultures of normal tissues (spleen, thymus, lymph node and subcutaneous tissue), in which comparable mononuclears and large spindle cells could be studied, showed that the normal mononuclear cell is the same in its characteristics as that in the sarcoma cultures, but the normal spindle cell of this strain of white rats is not the same as the sarcoma spindle cell, and chiefly in that the latter has double the number of chromosomes. From these observations it is evident that the spindle cell is the malignant cell of the tumor, and when the manner by which this cell acquires a tetraploid number of chromosomes becomes understood it is to be hoped that we will have an explanation of its malignancy. The observations of these investigators were made on the Walker tumor No. 1, although two other white rat sarcomata were studied, one a fibrosarcoma, the other a spindle-cell sarcoma. These gave essentially the same results.

VIRUS STUDIES

The studies being made by Mrs. M. R. Lewis and her co-workers on the behavior of the chicken-tumor virus have been directed in general toward solving the problem of whether the malignant principle is a living organism or merely a chemical substance. One phase of this work is the determination of the range of hydrogen-ion concentration in which the virus can be extracted and in which it will remain active. In a joint study with Dr. L. Michaelis, Mrs. Lewis has found that this virus remains active in buffer solutions having a hydrogen-ion concentration of 4 to 12, and becomes inactive in buffer solutions of pH 3 and in sodium hydroxide pH 12.5. These investigators point out the precautions that must be taken in interpreting experiments on the influence of hydrogen-ion concentration on living systems. It appears safe to conclude that the tumor extract showed a behavior towards certain buffer solutions different from that of embryonic cells, namely: the virus has a resistance for H^+ ions between 4 and 12, whereas embryonic cells have a resistance for a pH between 5 and 9; the nature of the buffer by which the pH is produced in the virus appears to be of no great importance, whereas for embryonic cells the nature of the buffer is very important, and an unfavorable condition of the buffer may be as harmful to the cell as an unsuitable hydrogen-ion concentration. From these observations it is apparent that chicken-tumor virus, at least in respect to its resistance to chemicals, shows a behavior very different from that of an animal cell or a protozoon; and if it is a living organism it is comparable to bacteria.

The influence of hydrogen peroxide on tumor virus is of interest because of the possibility of its injurious effect being due to the oxygen given off. In working on the catalase of malignant tissue Mrs. Lewis and Miss H.

Cossman found that as small amount as 10 per cent of hydrogen peroxide was sufficient to inactivate chicken-tumor virus. The hydrogen peroxide is evidently not decomposed in the presence of the virus and little or no oxygen is set free. Thus oxygen is ruled out and furthermore they found that pure oxygen can be bubbled through tumor extract without diminishing the activity of the virus. Neither does it seem to be due to a change in hydrogen-ion concentration or to the presence of acetanilid in the hydrogen peroxide. The cause of its effectiveness must remain uncertain for the present. The amount of catalase present in chicken tumor as compared with that in other tissues of the same animal and that present in tissues of normal animals was determined by these investigators who found that the tumor consistently showed very little catalytic activity, in this respect being like muscle.

A study has been made by Dr. J. R. Hobbs of the School of Hygiene and Public Health of the virus of a rare, highly infective disease occurring sporadically in rabbits, in certain countries of South America (Infectious myxoma). The disease is characterized by a purulent conjunctivitis associated with extensive subcutaneous nodules which on section are found to be tumors of myxomatous tissue, and small areas of the latter are found in the enlarged spleen and lymph glands. The eye secretions are infectious and in experimental animals the blood is infectious throughout the course of the disease, after the first 48 hours, and, if kept in a suitable container, remains so for long periods of time. The Department of Filterable Viruses was fortunate in obtaining tissues from infected animals in Brazil and from these Dr. Hobbs was able to transmit the infection to laboratory rabbits and to make an extensive study of the disease. He has studied particularly the distribution of the virus, the mode of contagion, immunity, filterability of the virus, its adsorption qualities, its viability and susceptibility to buffer solutions, various enzyme extractives and the ultra violet light. In studying the histopathology of the affected tissues he made tissue cultures of infected spleen and myxomatous tissue. In such cultures large stellate cells, that were supposed to be characteristic for the disease, are frequently seen. These do not appear to be present in cultures from normal rabbits but they can be obtained from spleens of normal guinea-pigs where they are known to be stroma or connective tissue-cells. In the living cultures no specific granulation of the myxomatous cells was noted that could be taken for a virus, nor did stains reveal any visible organism.

PULSATION RATE OF ISOLATED EMBRYONIC HEARTS

Five years ago (Year-Book for 1924) an account was given of the studies of Dr. W. H. Lewis upon the early rhythmic contractions of the chick heart, which pulsations continue for several hours after removal from the body and immersion in Locke solution. Since then this investigator has made an extensive series of control experiments to determine the various factors that modify the character and rate of the contractions. These include temperature, mechanical stimulation, changes in the CO₂ saturation of the air chamber and finally the salts and other substances of the immersing solution and their concentration. It is by such experiments that the nature of muscle contraction is being slowly interpreted, and also there is the

immediate practical result of the determination of the essentials of a perfusion fluid.

Early in the experiments it was found that whether the cover-glass was on or off the dish, in which the heart was being studied, made a great difference in the rate of the pulsations; the heart beat was from 20 to 100 per cent more rapid when the dish was covered. This striking difference was found to be due to the cooling of the fluid by evaporation when the dish was uncovered and its return of the drop to room temperature when the cover was replaced.

GROWTH OF ENDOCARDIAL CELLS

The work of Dr. M. Nishibe on tissue cultures of kidney tissue of the adult toad, described in the last Year Book, among other things brought attention to the outgrowth of endothelial cells which he could prove occurred in such cultures. Since then the work has been extended by him to the heart of chick embryos. Here he obtains outgrowths of both fibroblasts and endocardial cells. Abundant growths of the latter were obtained in cultures of ventricular trabeculae taken from the 6- and 7-day old chick embryo heart. That they are endocardial cells was demonstrated by histological examination of sectioned cultures where they could be shown to have direct continuity with the endocardium. The fact that endocardial cells and fibroblasts have a similar growth potentiality and are indistinguishable in the general appearance of their growth, or in their detailed form, makes it important to regard "pure cultures" of one or the other of them with some reserve, if there has been any possibility of contamination.

THE CENTRAL NERVOUS SYSTEM

MYELINIZATION AND ITS CORRELATION WITH REFLEX ACTIVITY, IN FETAL AND YOUNG KITTENS

In my last report an account was given of the histological studies of Dr. O. R. Langworthy dealing with the cortical areas in the cat and opossum of various ages and the degree of coincidence between structural development and areas of function as delimited by their response to electrical stimulation. Mention was also made of an extension of his studies to the determination of the temporal relation existing between the behavior of fetal and young kittens and the myelinization of their simpler reflex arcs. This work was finished during the year and the completed study has now been published in the Contributions to Embryology (Vol. XX).

The maze of neural connections in the adult brain makes difficult the tracing of pathways of even the simpler reflex activities. The functional aspect of the problem becomes greatly simplified by resorting to fetal and young animals, as was done by Dr. Langworthy, where only the first simple reflex patterns are developed. He has, as one means of disclosing these patterns, endeavored to correlate with the appearance of new behavior patterns definite morphological changes in the central nervous system. It is not yet clear which particular aspect of morphological development will eventually prove to be of most importance as an indicator of the initiation of activity. In studies, which I have previously referred to, the maturation of the nerve cells and the outgrowth of their processes was followed. In

this study of young kittens the criterion of development that was adopted is the deposit of the myelin sheath upon the nerve fibers, a phenomenon that can be readily and accurately demonstrated. The brain stems and spinal cords of newborn and young kittens were prepared with stains suitable for showing the progressive medullation of nerve tracts. The same animals had been previously tested as to the state of development of their cerebral motor cortex, their reflexes of progression and posture and other elements of behavior.

In the youngest animals studied there were medullated fibers in the spinal cord, enough to explain the reflex activity of the animal, but in the absence of the younger fetal stages one could not say that the tracts were medullated at the time they first functioned. The evidence indicated, however, that pathways become myelinated in the order in which they are developed phylogenetically. Certain general principles of medullation could be confirmed, such as that the ventral spinal roots myelinate before the dorsal. Myelinization occurs first in the cervical portion of the cord and proceeds thence in a caudal direction, which repeats the general direction of growth of the embryo. In the brain-stem the nerve of the most primitive sense organ (vestibular) and its connections become medullated early. Also the vestibular and spinocerebellar fibers are the first to reach the cerebellum; other cerebellar connections are tardy in obtaining their myelin. The medial longitudinal fasciculus is the first long pathway to be medullated, the vestibulospinal fibers the next. The posterior-column fibers of the cord myelinate slowly; the cuneatus fibers earlier than the gracilis. The cortico-spinal fibers do not show myelin until about two weeks after birth.

Certain correlations of reflex activity with medullation were established. As examples, the following may be mentioned: bilateral movements of the extremities begin to coordinate when the ventral commissural fibers of the cord receive their myelin sheath; the animals turn the body at the time when myelinated vestibular fibers reach the spinal cord; hind-leg movements become better coordinated when myelinization becomes marked in the lumbar portion of the cord. It is evident from Dr. Langworthy's results that the study of myelinization can be of great importance in obtaining information concerning the maturation of the nervous system, the knowledge of which is so essential to behavior studies.

BEHAVIOR OF POUCH-YOUNG OPOSSUMS AND MYELINIZATION OF NERVOUS SYSTEM

The study of kittens described in the preceding paragraphs reveals many things regarding the progress of myelinization of nervous pathways but it does not answer the question as to whether nerve pathways become medullated at the time when they become functional. Young kittens and even fetal kittens near term already have enough myelinated fibers to complete reflex arcs. By extending his work to the opossum Dr. Langworthy was able to study earlier stages. Since opossums are born immature they offer splendid material for the study of myelinization of the nervous pathways which can be followed from the beginning. The pouch-young are in reality air-breathing embryos and offer unique opportunity for the study of the development of reflex behavior, without the complication of asphyxia which is so difficult to avoid in other mammals. I have previously referred

to Dr. Langworthy's observations on their reactions to decerebration and to electrical stimulation of the cerebral cortex, and also the maturation of the cortical motor areas. During the past year he has completed a histological study of the spinal cord of 16 and the brain stems of 12 pouch-young animals, varying from 36 to 76 days old. In all of them a complete study of their functional behavior had been made.

First of all, he found that the animals are capable of performing many complicated acts before there is any evidence of myelin. The newborn can make their way into the mother's pouch, find a nipple and suck food and the necessary reflexes are carried over pathways in the nervous system that are not medullated until more than four weeks later. At birth there is good coordination of the forelegs; there are wide side-to-side movements of the head; and gross contractions of the trunk and abdominal musculature can be recognized. This precocious activity of the newborn opossum mediated along non-medullated pathways may be an exception limited to marsupials, just as, in the same species, the precocious development of the digestive tract, lungs and anterior limbs deviates from the normal procedure of morphogenesis. It is found, in fact, that the subsequent progress in the development of reflex behavior more or less parallels, and seems to be coordinated with, the appearance of myelinated pathways in the nervous system.

The material available to Dr. Langworthy permitted a study of the progress of medullation from its beginning and in his final publication a detailed account is given of it up to the seventy-sixth day, and comparisons are made with his studies of the same pathways in the kitten. He finds that as a general rule the efferent pathways are myelinated earlier than the afferent. In other words, the axones of motor cells and motor nuclei become medullated before these cells receive any myelinated afferent connections. Thus the ventral roots, ventral columns and ventral gray matter of the spinal cord medullate before the dorsal. Fibers extending into the spinal cord from the brain are myelinated earlier than the afferent pathways from the spinal cord to the brain. The efferent pathways from the pontine nuclei, deep cerebellar nuclei, and red nuclei are medullated earlier than the afferent connections. In the case of purely sensory pathways, the primary neurone is medullated before the secondary or tertiary. Finally, it is significant that the fibers of the central nervous system become medullated in the order in which they have developed phylogenetically. Thus the vestibular fibers are the first of any cranial nerve to acquire myelin. It will be remembered that as a part of our most primitive sense organ the vestibular area is the earliest landmark of the neural folds. What is said for medullation is also to a degree true for histogenesis of the neurones; they can be said to develop in the order of their phylogenetic rank. It is possible that it may prove that medullation is but an element of histogenesis and is not to be relied on as a specific evidence of functional onset.

MYELINIZATION IN A 7-MONTH HUMAN FETUS

As rapidly as possible the study of the sequence of medullation of nerve tracts and its correlation with functional development is being extended from the laboratory animals to men. Toward this end, Dr. O. R. Lang-

worthy has completed a survey of the medullated tracts in the brain stem of a seven-month human fetus, an account of which has been published in preliminary form. He finds that the optic and olfactory nerve trunks at this time contain no medullated fibers. In fact, the only myelinated fibers anterior to the midbrain are those found in the globus pallidus and a few in the medial lemniscus extending into the thalamus. All of the true cranial nerves (third to twelfth pair) are medullated, although the amount of myelin is not the same in all of them. The three eye-muscle nerves have a heavy coating, the tongue-muscle nerve has less. The vestibular fibers are more heavily medullated than the cochlear. As for the trigeminal nerve, the motor fibers stain more intensely than the sensory. Of the descending paths from the brain stem to the spinal cord the following are medullated: vestibulospinal; reticulospinal; tectospinal; and the medial longitudinal fasciculus. No myelin is yet seen in the two long motor projection tracts, the corticospinal and the rubrospinal.

BRAIN OF ORNITHORHYNCHUS

This strange animal, placed somewhere between reptiles and marsupials, in some respects unqualifiedly mammalian, in others more allied to the reptiles and birds, is an irresistible challenge to the interest of the philogenist. Its brain is no less perplexing than its general anatomy. It is therefore as a matter of especial note that I refer to the recent monographic study of the ornithorhynchus brain by Dr. M. Hines. The opportunity of studying this rare material and aid in the prosecution of the research was generously given the investigator by Professor G. Elliot Smith and Professor J. T. Wilson, both of whom have had long acquaintance with the monotreme central nervous system, and it was in their laboratories that most of her work was done. Under these favorable circumstances a monograph was produced by Dr. Hines that is destined to serve as an invaluable reference work for the comparative neurologist.

Among the significant features that are pointed out by Dr. Hines may be mentioned the great hypertrophy of the sensory division of the trigeminal nerve, associated with an extensive development of the general cutaneous sensibility, and especially the snout area, the centers of which lie chiefly in the brain stem. There is an enormous development of the peduncular systems, which together with the large fifth nerve give the medulla oblongata its peculiar form. That the formatio-reticularis is of greater relative importance than in higher forms is evidenced by its large, heavily myelinated, nerve fibers, connecting the tegmental zones of the thalamus, midbrain and medulla, and by its many large motor-like cells, which in some degree are assembled in nuclear groups. The medial lemniscus, subserving bodily muscle sense is unusually large and it is strikingly augmented rostral to the nucleus gracilis and cuneatus, which is apparently correlated with the excessive development of the general cutaneous sensibility of the head requiring a finer muscular adjustment in response to its stimulation. It is evident that enlargement of the muscle-sense systems does not signify larger muscles or greater numbers of muscle fibers, but rather is an indication of a finer adjustment of those already developed.

Among the co-ordinating systems of the medulla, Dr. Hines has shown the correlation of the olives to the functional requirements of different muscle groups. The inferior or principal olive is poorly developed, except for its frontal pole, which meagerness is evidently associated with the absence of independent lateral hemispheres of the cerebellum. On the other hand the median olive is relatively large. The cerebellum is essentially mammalian in its medial and lateral nuclei, but is avian in having negligible lateral hemispheres of the middle lobe, resembling in its general morphology the anterior and middle lobes of birds. The midbrain is definitely mammalian, although the motor systems are larger than in many other mammals, and in this respect it resembles the reptile midbrain. The thalamus shows a striking hypertrophy of the medial and ventral nuclei of the dorsal thalamus and of its thalamo-tegmental and peduncular systems. In the corpus striatum particular interest is linked with that intricate region composing the amygdala. The telencephalon is typically mammalian with respect to the olfactory apparatus and its connections with the thalamic centers. The cortical lamination was not studied. That may never be necessary in view of what has been done and what may be done in the future in the opossum, an almost equally primitive form. The ornithorhynchus can scarcely ever become an experimental animal which is essential for cortical studies, whereas the opossum is feasible for that purpose, as the reader of these reports will have seen.

ELECTRICAL EXCITABILITY OF THE MOTOR CORTX

In a study that received the Howell Prize award for 1928, Dr. S. S. Tower has made observations on the threshold for electrical excitability of the motor cortex of anesthetized cats and dogs, over periods of from two to six hours and has determined both its constancy in the same animal and its comparability from animal to animal. It was first necessary to establish a "control" threshold including uniformity in the depth of anesthesia, the temperature of the motor cortex (body temperature), and the type of electrode used and its mode of application. It goes without saying that the physical condition of the cortex must be the same. The value of the threshold was measured in centimeters distance of the primary from the secondary coil. With this uniformity in the technical procedure results were obtained which gave a threshold, characteristic for each of the two species studied, and at the same time fairly constant from animal to animal within the species. This, it is to be remembered, is under anesthesia. Also the threshold only applies to motor reactions. Dr. Tower found that in the stage of anesthesia used, extensor tone was always present in the limbs of cats and often in dogs. Frequently this extensor tone was inhibited at a definitely lower threshold than that for muscular contraction. In other words, the reaction of lowest threshold obtainable from the motor cortex appears to be the inhibition of extensor tone.

The experiment was tried of varying the brain volume and intracranial pressure by intravenous injections of hypertonic and hypotonic solutions. It was found that a moderate increase of intracranial pressure or an expansion of brain volume is without influence on the excitability of the cortex. On the other hand a decrease in brain volume is accompanied by a definite

decrease in the excitability of the motor cortex, whether accompanied by a lowered intracranial pressure or not. That the decreased pressure was not the important thing was shown by obtaining the same results with the cranium open to atmospheric pressure and with the cranium closed and the pressure as low as -44 mm. None of the procedures used seems to heighten the irritability. The possible rôle of intracranial pressure in producing changes in cortical excitability is of course important in its bearing on the problem of convulsive seizures and epilepsy.

CORTICAL LOCALIZATION OF MOVEMENTS OF THE FACIAL VIBRISSEÆ

The facial vibrissæ, which in some mammals are so highly developed as a head-protecting mechanism, have been studied in the opossum by Dr. E. Huber and Dr. W. K. Smith. In this animal, as in many mammals, their effectiveness is increased by a well-developed muscular equipment, providing a nicely controlled and wide range of movement. They were able to demonstrate that these movements are effected through contraction of the facial muscles. They have also pointed out the close association between the site of the vibrissæ and an uncommonly rich cutaneous nerve supply from the trigeminus which characterizes this area. They suggest that the facial vibrissæ may possibly have been a determining influence in the distribution of the trigeminal elements, the effects of which persist even in those forms in which the vibrissæ are not represented. Still more important are their observations on the cortical representation of this delicate tactile mechanism. The facial area is poorly localized in the cerebral cortex of the opossum. The movements, which they have shown may be elicited from the vibrissæ by stimulation of this area, are therefore particularly striking. This study of Dr. Huber and Dr. Smith on the vibrissæ is nearly completed and a preliminary account of their observations has already been published.

SKELETAL MUSCLE TONUS

In previous reports reference has been made to the disputed question as to the existence of dual innervation (somatic and sympathetic) in muscle tonus and to the important observations of Dr. Coman, who proved that it is not true in the dog and cat. He showed that in these animals the sympathetic is in no way responsible for tonus and that loss of the somatic innervation of the limbs is followed by complete abolition of tone. There still remained the possibility that the matter might be different in goats, which was the animal used by the proponents of dual innervation. During the past year Dr. M. Hines and Dr. S. S. Tower have, therefore, repeated similar experiments on goats. *

In three young goats the cervical sympathetic chain was removed on one side which was followed by the complete Horner syndrome for that side, proving the effectiveness of the operation. From 30 to 60 days later the animals were decerebrated and it was found that no difference in tone could be detected between the desympathectomized fore limb and the normal. In two other goats the cervical sympathetic rami were cut with a technique like that used by those investigators who had reported a dual innervation. Dr. Tower and Dr. Hines were not able, however, to obtain the claimed evidence of dual innervation. They found that in the use of the limbs in standing,

walking and running, under ether rigidity and under decerebrate rigidity there was no appreciable difference in tonus in the operated from the unoperated side. What variation occurred, at no time exceeded the variation in the entirely normal hindlegs of the same animal. One must conclude therefore that tonus as a component of skeletal muscular function is not dependent on an intact sympathetic innervation of the muscle. It may be shown later that the sympathetic nervous system exerts subtle moderating influences upon tonic activity, of a trophic or nutritional character, which these experiments were not designed to detect.

THE MONRO-KELLIE HYPOTHESIS

The Monro-Kellie hypothesis, in its recent form, is the teaching that the contents of the cranium are at all times relatively fixed in volume, and that variation in any of its three constituent elements (brain tissue, blood and cerebrospinal fluid) must be compensated for by reciprocal variation in the quantity of one or both the other elements. The factors of intercranial pressure are of immediate practical importance to the surgeon in any procedures involving operation on the central nervous system, as well as to the physiologist concerned with the circulatory phenomena of this important region. Several years ago Professor L. H. Weed and Dr. P. S. McKibben showed by experiments in the living animal that the volume of the brain could be altered by intravenous injection of solutions having an osmotic pressure higher or lower than that of the blood. They demonstrated that the alteration in cerebral volume and the pressure of the cerebrospinal fluid is effected by the interchange of water and salts between the blood and the nervous system with its fluids. This could be carried to the extent of obtaining negative pressures of the cerebrospinal fluid, indicating that the doctrine was correct as to the rigidity of the bony case in which the central nervous system lies. Later, Dr. Weed and Dr. W. Hughson devised further experiments which proved conclusively that the intactness of the cranial vault is essential for the production of these negative pressures.

These experiments of Dr. Weed and his associates, though showing that the Monro-Kellie doctrine is essentially sound, did not exclude certain minor theoretical possibilities such as slight variations in the intradural vascular bed or in the epidural tissues and the possible expansion or collapse of the spinal dura and the membranous spinal ligaments or the movement of fluid along potential perineural channels. During the past two years Dr. Weed has resorted to further experiment for the testing of these finer limitations. He has studied the influence of postural changes on the pressure of the cerebrospinal fluid, using a tilting table by which the animal could be abruptly changed from horizontal to vertical positions, either head-down or tail-down. He established, first of all, that the lumbar pressure is higher when measured in the erect as compared with the prone position. When the animal is restored from the head-down postures to the horizontal position, the pressure temporarily falls below its original level, indicating that increased intracranial pressure causes increased absorption of the cerebrospinal fluid. The reverse occurs in tail-down postures, and it is evident that the major absorption of the cerebrospinal fluid is in the head region. When the pressures are simultaneously taken in the occipital and lumbar regions

they are found the same in the horizontal position; when the animal is turned head-down the lumbar pressure becomes negative and the occipital is greater than where a single needle is used. The occipital pressure may increase from a normal of 120 to as much as 240 mm., while the lumbar pressure in the same experiment sinks to minus 100 mm. These results show that there must be an inward collapse of the dura mater which allows a postural dislocation of the cerebrospinal fluid, and particularly in the lumbar and sacral regions. To this there is to be added the minor part that may be played by the theoretical dilatation of the intradural veins.

Though the spinal dural sac does not serve as an absolutely rigid container, the Monro-Kellie doctrine must be considered essentially correct, and there is a relative rigidity of the spinal dural cavity that supplements the more complete rigidity of the cranium. Apparently it is by virtue of this fact that the mammalian central nervous system is protected against harmful changes in pressure due to postural adjustments, as would be the case were it subject to the full effect of a hydrostatic column of fluid.

THE MENINGES IN AMPHIBIA

The study of Dr. L. B. Flexner on the development of the meninges in normal and experimental specimens of amphibian embryos (*Amblystoma punctatum*) was published in its final form during the past year. Using the normal specimens as descriptive material and as controls he made a series of transplants of pieces of brain and spinal cord, both with and without neural crest cells, to the right flank of the recipient in some cases and to the right branchial region of others. In the normal embryos the process of the morphological differentiation of the brain membranes was studied and the relationship of the spread of arachnoid fluid to this differentiation was observed. In the transplanted material it was sought to determine the influence upon the formation of the membranes of the presence or absence of neural crest cells and to test the influence of fluid-circulation in the differentiation of the meninges.

It was found by Dr. Flexner that the process of differentiation of the meninges in amphibians closely agrees with that of the mammals, with the final formation of three definitive membranes. In this process the extraventricular spread of cerebrospinal fluid can be traced and it seems probable that this fluid may be the exciting factor in the differentiation. Fluid-spread was demonstrable in most of the experiments where a dura and sub-arachnoid space developed about the transplant. In the animals that completely lacked differentiated membranes there was no fluid-spread. Considerable attention was given to the possible origin of the leptomeninges from the neural crest cells (ectodermal mesenchyme), as opposed to the mesenchymal origin of the dura. For this he could find no satisfactory evidence and concludes that entodermal and ectodermal mesenchyme enter alike in the formation of the dura, arachnoid and pia. It is of interest to add that the roof of the fourth ventricle of the amphibian has an area corresponding to the area membranacea which was found by Dr. Weed to play such an important part in the spread of cerebrospinal fluid in man and pig, and which has been identified in many mammals and in the chick.

ORGANS AND MECHANISM OF REPRODUCTION

MENSTRUATION AND INTERMENSTRUAL BLEEDING

The mechanism of menstruation has been one of the long-standing riddles of physiology and it is only in recent years, with the revelation of the outlines of the oestrous cycle, that the solution of its significance seems to be at hand. Progress has been greatly aided by resort to a menstruating experimental animal, the *Macacus rhesus*, which has now become established as a laboratory resident. The observations that have been made by Dr. C. G. Hartman on uterine bleeding are among the first important products of the Carnegie colony of monkeys which he has been so successful in organizing. He has found that in the macaque, and the same is doubtless true for man, there are to be distinguished three types of uterine bleeding. First of all there is the typical periodic bleeding of menstruation, occurring at approximately monthly intervals. This is usually associated with a preceding ovulation, but not necessarily so; menstruation may occur in the complete absence of ovulation. In fact, evidences have been discovered by Dr. Hartman of ovulation being seasonal in character. From thirty laparotomies performed during the menstrual flow, he found that degenerating corpora lutea are more likely to be present during the Fall and Winter months than during Spring and Summer.

A second type of uterine bleeding is one associated with pregnancy. It is a slight bleeding that begins from 15 to 20 days after conception and continues for three weeks. It may attain the intensity of a light menstrual flow. From animals sacrificed at the time of bleeding it was found that the blood reaches the lumen of the uterus from greatly dilated, blood-filled uterine glands. This type of bleeding resembles the "placental sign" that occurs in the rat and it promises to be a valuable early sign of pregnancy. Dr. Hartman has observed it sixteen times in sixteen pregnancies in his animals.

A third type of uterine bleeding is one that occurs in the mid-interval between the regular menstrual periods, in monkeys, and probably in man. It is detectable only by microscopic means, as a few red-blood cells found in the vaginal washings. Dr. Hartman regards this bleeding as the homologue of the prooestrous and oestrous hemorrhage in the dog. It is more or less synchronous with ovulation, though not an invariable sign of ovulation as first thought. Its periodic regularity is proof that it is part of the oestrous-cycle picture and in that way it will form one of the contributory external signs of what is occurring in the ovaries and uterus. It is needless to point out that such a readily detectable sign of the time of ovulation will be of great value to the embryologist who is looking for timed material, as well as to the student of oestral phenomena.

GESTATION AND PARTURITION IN *MACACUS RHEBUS*

Preliminary accounts of the observations of Dr. Hartman on gestation in the monkey were given in the report of last year. Since then complete descriptions of the newborn baby have been prepared for publication. The year has provided opportunity for confirming and extending these important studies. There have now been 18 pregnancies which have been followed in

the colony. Of these 15 resulted in full-term young; one case was terminated intentionally for obtaining a desired stage of the embryo and uterus; and in two the fetus was expelled prematurely. Parturition was observed in 7 cases.

With the cooperation of Dr. O. L. Tinklepaugh of Yale University and Mr. C. B. Clark very satisfactory motion picture records were made in five cases, fairly well covering the various phases of parturition. These records will be of great value for a detailed study of this important representative of instinctive behavior. Dr. Tinklepaugh spent several weeks with us during the height of the parturient season, principally for the purpose of studying the capacities and behavior of the newborn babies and during the first two weeks of their infancy. This is new ground and provides a starting point from which one can trace behavior backward into the fetal period.

CASTRATION STUDIES

Combining histological studies of the grafted tissue with functional tests of the animal's activity, Dr. C. P. Richter and Dr. G. B. Wislocki have made a series of testicular grafts in castrated young male and female rats. Castrated animals register fewer revolutions of the drum of their cage than normal ones; but when testicular grafts "take" successfully, evidence of their function is recorded by an increased activity of the animals. These investigators have studied the grafted testicular tissues, of which the functional capacity had been recorded in terms of animal activity, and have determined the amount of growth attained following transplantation and the particular histological elements that give evidence of being responsible for the functional results. They find that the graft usually increases in size both in the functional and non-functional cases. In the "non-takes," however, the tissues are degenerated, acellular and fibrous. What exists in the way of growth is confined to an increased amount of acellular necrotic interstitial tissue. Size alone is not a sufficient criterion of a functional graft. In the "takes" it is found that there is a survival of the cells constituting the testis and particularly the interstitial portions of the organ. There occurs a proliferation of this specific element of the gland and they have demonstrated that it is not an invasion of a degenerating testis by macrophages. They did this by staining animals containing grafts, vitally with trypan blue, and subsequently finding that the cells of the interstitial tissue had not stained vitally, though the fibrous zone encapsulating the graft showed abundant vitally stained macrophages. Besides an actual increase in the amount of specific cellular interstitial tissue in the "takes" there is an establishment of lymphatic communications. India ink injected into the grafts drained through lymphatics into nearby lymph nodes. As for the tubular elements of the testis they apparently do not function and are found in various degrees of degeneration. They fare somewhat better, however, in male animals than females. On the whole it is found that the increase in activity of an animal receiving a testicular transplant stands in direct proportion to the state of preservation of the graft, and that the most important part of the testis for the production of the activity appears to be its interstitial tissue.

PARASITES IN THE OVARIES OF THE ANT-EATER

In studying the reproductive organs of the three-toed ant-eater Dr. G. B. Wislocki found the ovaries in specimens from Nicaragua and Guatemala invaded by nematode parasites. Since the specimens were obtained at different times and in different localities this form of parasitism may prove to be commonly present in this genus. This is the first time that parasitic worms have been recorded in the ovaries of any group of mammals.

PLACENTATION

NATURE OF THE PLACENTAL SIGN

An extravasation of blood in the endometrium or into the uterine cavity occurs in many mammals during early gestation, the significance of which has been quite unknown. There is evidence that these extravasates serve some need of the embryo; possibly they are an available source of iron. To obtain further light on this problem Dr. Wislocki and Dr. Hartman have studied the phenomenon as it occurs in the macaque, which is ideally suited through the fact that the reproductive cycle in this primate can be closely followed and the exact date of mating controlled. They were able to obtain a specimen which was killed at the moment of maximum bleeding and the entire genital tract was perfectly preserved and prepared for microscopical study. The source of the prolonged leakage of blood was traced to the uterine glands which were found distended with blood, much of it undergoing hemolysis. By far the greater part of this blood can not escape, because most of the glands are walled in by the two placenta. At the interval between the margins of the placenta, however, the glands open freely into the uterine cavity—a persistent slender lumen encircling the fetal sac. Through this passage there is free opportunity for the extravasated blood from a minority of the glands to drain into the cervix and thence into the vagina. The localized extravasations of blood that occur in the carnivores, during early pregnancy, along the margins of the zonary placenta, and known as border hæmatomata, appear to be of similar nature, although here none of the blood escapes into the vagina. In the rodents extravasation of blood occurs into the uterine cavity along the placental borders and one can demonstrate the resorption of this blood by the highly phagocytic epithelial cells of the yolk-sac. Some of it escapes into the vagina and constitutes the “placental sign.” The detailed description of the placentation of the macaque given by these investigators is much more complete than has heretofore existed and, in view of the increasing importance to the laboratory of this particular animal, the need of this information has been urgently felt.

PLACENTAL LABYRINTH OF THE SLOTH

The complicated structure of the placenta of the sloth has led to conflicting conclusions regarding its homologies. In my report of last year I referred to Dr. G. B. Wislocki's studies upon the reproductive tract of this animal and also that of the closely allied two-toed ant-eater. During the past year a further study by him has been made of these forms with attention directed particularly to the finer structure of the placental labyrinth.

By having a sufficient number of stages at his disposal, and particularly the earlier ones, he has been able to show conclusively that these labyrinths are transitional between the syndesmochorial and endotheliochorial types, resembling in general that encountered in the carnivora. There can be no further questions as to the trophoblastic nature of the layer covering the maternal vessels and of the transformation of the endothelial cells lining them. He also traces completely the fetal origin of the epithelioid cells from the time they arise in the fetal stroma until they arrange themselves as a sheet of cuboidal cells along the margin of the trophoblastic membrane.

PRIMATE PLACENTATION

The student interested in the problems of implantation of the primate ovum is indebted to Dr. G. B. Wislocki for his extensive study on the placentation of primates, published in the last volume of the Contributions to Embryology (Vol. XX). In this is assembled the results of his own work, extending over a period of five years, and a review of the work of other observers. His own observations were made on a considerable series of both Old and New World monkeys, several genera of which had not hitherto been studied. Limiting his attention to the Simiæ he has recorded many personal observations, and through assembly and analysis of the fragmentary data existing in the literature he has provided us with a valuable revision of the subject based on a comparative point of view. As to its general form, the placenta is subject to great modifications, thus some platyrrhines and some catarrhines have a double placenta, and others, a single placenta. The single placenta is the most common and is probably nearer the stem form; whereas placental duplicity is more specialized. Thus the form is not of much classificatory value. In its finer structure, however, one finds the platyrrhine placenta more primitive than the lower catarrhine, and the latter in turn more primitive than that of the anthropoids. This gradation rests on the manner and degree of proliferation of the trophoblast in these forms. It is profuse in the platyrrhines, less so in the catarrhines, and in the anthropoids there is left only the syncytial network thinly covering the villi. The anthropoids and man have another feature that distinguishes them from monkeys, namely, interstitial implantation with the resultant formation of a capsularis. Except for minor points of difference in other respects the form and finer architecture of the mature placenta in anthropoids and man are identical.

Dr. Wislocki concludes from what is known of the placenta that the stem forms for all the existing groups are characterized by trophoblastic invasion of the endometrium and the establishment of a labyrinthine or villous placenta. The fact that this is not true for lemurs he would explain on the basis of their being highly specialized in respect to the placenta. Apparently the majority of the mammals that are archiac or near the stems are deciduate, whereas those that possess a diffuse type of placentation are the extremely specialized mammals. It would thus appear that the deciduate type of placenta is probably the more primitive and the diffuse placenta is a specialized offshoot from it.

ADULT AND COMPARATIVE ANATOMICAL STUDIES

HISTOLOGICAL STUDIES OF THE PORPOISE

As part of the booty derived from the expedition for obtaining whale material (porpoises) at Cape Hatteras, referred to in my last report, Dr. G. B. Wislocki obtained the pituitary glands from six specimens. These have been studied microscopically by him and he finds that they possess several features that are peculiar to this species. Very little has heretofore been done to correlate the structural morphology of the hypophysis with its biological functions of regulating growth and reproduction. It would seem that the morphology of an endocrine gland of this type might be constant, but one finds, on the contrary, that it differs considerably in different mammals. Therefore, it is going to be necessary to determine the structural elements that are common to all mammals, as well as the deviations in individual species. In the porpoise Dr. Wislocki finds that the *pars intermedia* is completely lacking. The *pars distalis* is composed of lobules more pronounced than in other mammals. They contain the usual three types of cells. Many of the basophile and some of the eosinophile cells, however, contain both acidophilic and basophilic granules, suggesting transitional forms. The cells also seem to have a definite arrangement in that the periphery of each lobule is formed by a row of granular cells, whereas the center consists chiefly of chromophobe cells with occasional eosinophile, basophile or fat cells. In the *pars tuberalis* the epithelial cells lining the follicles are chromophobe. The *pars nervosa* is composed solely of blood-vessels supported by neuroglial tissue.

Because of the special breathing requirements of the porpoise, the lung structure becomes of particular interest. This has been studied by Dr. Wislocki in his Hatteras material and a preliminary account of his observations has appeared. He finds a remarkably well-developed equipment of connecting bronchial cartilages which extend to the junction of the smallest bronchioles with the atria. Muscle fibers are absent in the bronchial tree but are found in bronchioles under 1 mm. in diameter, where they are arranged as a series of rings or sphincters, capable of closing off the alveoli following inspiration. Throughout this same region these terminal bronchi are lined with flattened epithelium with a rich network of capillary blood-vessels, and it would appear that they have a respiratory function as well as the alveoli. The porpoise has a powerful recoil mechanism. The structural basis for this is found to consist of two well-defined elastic-tissue membranes in the bronchial tree and a large amount of elastic tissue in the thickened pleura and in the walls of the atria and alveoli.

COMPARATIVE MYOLOGY AND OSTEOLOGY OF THE SEAL AND SEA LION

Our anatomical group has been strengthened by the appointment of Mr. A. Brazier Howell as lecturer in comparative anatomy in the Johns Hopkins Medical School. Mr. Howell had previously cooperated with us in the expedition for obtaining whale material and brings with him a wide experience in anatomy and natural history. While at the United States National Museum he had been studying the osteological and myological

adaptations of marine mammals to the necessities of aquatic locomotion, and particularly of the eared (sea lion or *Zalophus*) and earless (*Phoco*) seals. This required a detailed study of their muscular and skeletal equipment. A complete account of his observations with an analysis of the differences occurring in these two genera was published this past winter in the Proceedings of the U. S. National Museum.

ANATOMICAL STUDIES ON SLOTHS

Frequent reference has been made to the studies by Dr. G. B. Wislocki on placentation in sloths. Taking advantage of the abundant material at his disposal, he has extended his investigations to a survey of all the soft parts of these extremely specialized and widely aberrant mammals, more particularly for the purpose of analyzing the differences between the tridactyl and didactyl forms and the correlation of their morphology with their posture and climbing habits. Among his observations on the external characters he finds the interesting fact that in the development of the hair in fetal life, of the three-toed sloth, the direction of the hair lines is such as to produce a pattern that will facilitate the maximum shedding of rain water for the adult posture. In the two-toed sloth the posture and corresponding hair pattern is entirely different. Whether this is similarly prepared for in fetal development could not be verified because of lack of fetal material in that form. One would expect it.

The vascular system of the sloths exhibits an unique arterial specialization in the extremities that appears to be correlated with prolonged maintenance of postural tone and with slow movement. Instead of a single main artery, the vascular supply of the extremity is provided by a bundle of vessels rendered incompressible by a tubular framework of dense connective tissue, evidently a provision for insuring an adequate blood supply against the protracted contraction of the limb muscles. Dr. Wislocki finds this arrangement in both the two-toed and three-toed sloths and also in an arboreal ant-eater (*Cyclopes didactylus*). Among other vascular peculiarities, the sloths have a large venous pathway through the vertebral canal, supplementing and anastomosing with a double posterior vena caval system.

Dr. Wislocki gives us the first description of the lymphatic system of the sloth, based on injections with India ink of the lymph channels, and a study of the lymph nodes. Of the abdominal viscera he made special study, grossly and microscopically, of the gastro-intestinal tract, liver, gall-bladder, pancreas, spleen, adrenals, kidneys and the male and female reproductive organs. Similarly he studied the thoracic viscera in addition to the thyroid glands, hypophysis and the retina. The comparison that is made of the two varieties of sloth is based largely on the viscera and other soft parts, instead of being largely confined to the skeletal elements, as the comparative anatomist is often forced to do. Throughout the study many new observations are made and particularly in the reproductive tract which was studied in great detail. In referring to the diverse development of the gall-bladder in the *Xenarthra*, Dr. Wislocki points out that it is best represented in the armadillo and degenerates into a simpler form in the ant-eaters and is still present in the two-toed sloth, but is entirely absent in the three-toed sloth.

THE ILIUM OF ADULT PRIMATES

While a National Research Council Fellow in Professor Todd's laboratory Dr. W. L. Straus jr. made an extensive series of measurements and observations on the pelvic bones, particularly the ilium, of the various Primates. From the material at his disposal at the Western Reserve University, supplemented by specimens at the United States National Museum and the American Museum of Natural History, Dr. Straus has completed two studies of the ilium, one restricted to man, which I referred to in my last report, and one covering the Primates has just appeared in its published form. His material included abundant and thoroughly representative species of Insectivores, Lemuroidea, New-World monkeys, Old-World monkeys, anthropoid apes and man. In addition he has had access to the pelvic remains of an American fossil primate, the *Notharctus*. This he found to be very definitely of the type seen in the existing genus *Lemur*.

The most reliable sexual character of the primate ilium was found by Dr. Straus to be the "interiliac index." In man it is, on the average, larger in males than in females, both in white and negro stocks, with very moderate overlapping. It means that the true pelvic segment is relatively longer in the female than in the male sex. This difference is also present in the gorilla, chimpanzee, orang-utan, gibbon and macaque. It, however, progressively decreases in the order of the animals named, gorilla standing closest to man. From the phylogenetic standpoint, he finds that in the more primitive mammals, including lemurs and monkeys, the development of the ilium is chiefly in a craniocaudal direction, as typified by the long axis of bone. Beginning with the gibbons, and possibly the baboons, the development proceeds increasingly in a dorsoventral direction. Dr. Straus suggests the possibility of this trend being connected with change in posture. The anthropoid-ape type of ilium is apparently not to be placed as intermediate between the human and lower mammalian forms. It has its own specializations and characteristics that are as definite as those of man and one must conclude that the human type was not derived from it but more likely from some primitive member of the preanthropoid group. Among the phylogenetic changes identified by Dr. Straus in the primate ilium are: increase in relative iliac width; widening of the iliac surface and differentiation of an anterior superior iliac spine; migration of the iliac surface from a ventrolateral to a medial position; development of an iliac fossa; widening of the gluteal surface; modification of the sacral surface; and formation of a greater sciatic notch.

FACIAL MUSCULATURE

A series of experiments has been conducted by Dr. C. F. DeGaris in an effort to determine the relation of the muscle groups, supplied by the facial nerve, to the different cell groups in the nucleus of origin of the nerve. Individual branches of the nerve were extirpated in the cat and, after sufficient time had elapsed for chromatolysis, the brain was studied microscopically by the Nissl method and the grouping of the chromatolytic cells in the facial nucleus was studied. This work is still in progress but the experiments already indicate that the phylogenetic grouping of the facial muscles is to

some extent reflected in the cell arrangements of the facial nucleus and also the same may be said for the functional grouping of the muscles.

A correlation has been found by Dr. E. Huber between the evolution of the facial musculature and a greatly increased cutaneous nerve supply from the trigeminal nerve. He points out that, as the facial musculature evolved from what in the promammal must have been a restricted area in the neck, it spread over the whole head, becoming differentiated into a large number of distinct muscles. The facial nerve participated in this development, but only with respect to its motor elements. There may even have been a positive loss of cutaneous fibers and one finds no more than meager vestiges of them about the outer ear. On the other hand, the trigeminal nerve responded with a greatly increased cutaneous supply in proportion to the increased importance of these regions, particularly well shown where the facial muscles undergo high differentiation such as about the snout and in the region of the facial vibrissæ.

Dr. Huber has been extending his studies of the facial muscles to the specific problem of the origin of mimetic musculature and facial expression. For this purpose he has had access to a wide variety of primate material on which, over a period of several years, he has made observations of the living animal supplemented by painstaking dissections of the structures involved. In the prosimians the facial musculature is primitive in its general plan, being adapted solely to the motion requirements of the mouth, eyes, ears and the muscular elements of the tactile vibrissæ. In the platyrrhine and catarrhine monkeys the differentiation progresses, as one ascends the primate scale, toward definitive muscles of facial expression. A considerable mimetic ability is reached in the relatively hairless face of the higher catarrhines, and in the anthropoid apes the range of individual features of expression is quite large, though still crude and grimace-like as compared with man.

As for man, the elaboration of facial expression depends largely on the central mechanism, the differentiation of which is found by Dr. Huber to precede that of the peripheral structures. His detailed studies of the morphology of the latter reveal a tendency toward fuller differentiation into distinct muscles in the glabellar and supra-orbital regions and about the mouth, which are the seats of most active facial expression. Voluntary coordinated control of these varies in individuals and determines their relative ability in mimetic power. Racial differences in expression though in part due to structural differences in musculature and character of skin are regarded by Dr. Huber as principally dependent on central factors. He distinguishes the grimace as a crude group action of mimetic muscles, of an older phylogenetic order, that occurs only exceptionally in man, under the condition of spontaneous emotional outbursts.

MUSCLES OF THE FOOT

The foot musculature of a highland gorilla (*Gorilla beringei*) has been studied by Dr. W. L. Straus jr., and a preliminary report of his observations has been published, a description in its final form being now in course of preparation. This is the first time that the foot of this species has been studied in detail. It has a particular interest in respect to the anatomical

adaptations that occur in this anthropoid to a plantigrade mode of locomotion. A few studies have been made of the lowland gorilla, the plan of whose foot seems to be followed in general in the highland form. Because of the factor of variability it is to be hoped that many specimens of both species will in time become available for anatomical study.

Studying the interosseous muscles of the foot among Primates, Dr. Straus has traced the shift that occurs in the arrangement of these muscles relative to the axis of the foot. In most mammals including the New- and Old-World monkeys they are arranged with reference to an axis passing through the third toe. Among the Lemuroidea and Tarsiodea, who exhibit an extreme elongation of the fourth digit, the axis may shift to that digit. On the other hand, among the anthropoid apes there is a shifting from the third to the second toe. In the gibbon they are arranged around the third; in the orang-utan and chimpanzee the axis is usually through the third but also frequently through the second. The gorilla usually has the axis through the second toe. That the axis in man is through the second toe seems to be correlated with the lengthening of the second digit and the development of the inner border of the foot. The interesting observation is made that the arrangement characteristic for man and gorilla occurs now and then among the less terrestrial anthropoids which suggests that the variation already exists in the stock from which both anthropoids and man are derived.

PERMEABILITY OF EPITHELIUM OF GALL-BLADDER

Dr. W. L. Winkenwerder, from a series of experiments on the gall-bladder of the cat, has shown that the lining epithelial cells are not all equally permeable. He distinguishes two types, or functional states, of the cells; the typical columnar cells with cytoplasmic granules stainable with mucicarmine, and cells devoid of granules and containing slender dense nuclei. The former is much more abundant but between the two types there are all gradations. When a balanced solution of potassium ferrocyanide and iron ammonium citrate is injected into the gall-bladder its resorption can be traced by fixation of the tissue in acid formalin which precipitates the solution as Prussian blue. This experiment was carried out by Dr. Winkenwerder and he found on microscopical examination of the gall-bladder walls that there was but little Prussian blue precipitated in the granular type of epithelium, whereas the less numerous non-granular cells contained large quantities of the dye in their cytoplasm. Evidently following secretion, with attendant exhaustion of granules, the cells are more permeable to solutions of this character. The Prussian blue was traced into the sub-epithelial tissues, where it was found principally in the blood capillaries and the veins penetrating the muscularis into the subserosa. Very little was found in the tissue spaces and still less in the lymphatics.

THE VASCULAR SYSTEM

After a prolonged series of experiments Dr. E. C. Hill has devised a radiopaque injection method that gives much more dependable results for the radiographic study of the vascular system than was heretofore attainable. He uses bismuth oxychloride suspended in a solution of gum acacia and through his own extensive experience, dating as far back as his studies

on the testis in 1906, he has been able to perfect the necessary details of the technique of injection. It is now not only possible to make preparations that show the gross vascular pattern but tissues may be injected with a suspension fine enough to render them suitable for microscopical study, making the technique applicable to embryological material. The method has had the "acid test"; it has been used by several outside workers with gratifying success.

Dr. E. Grodzinski, a guest in the laboratory during the past winter, found that in the fossil reptiles, *Apatosaurus excelsus* and *Diplodocus carnegiei*, there are traces of lymphatic hearts that leave an imprint on the caudal vertebræ of sufficient clearness to indicate their size and topography. They are evidently similar to the lymphatic hearts that are found in the tail near the pelvis in recent reptiles—where they lie in close relation to the transverse processes of the caudal vertebræ.

An anomaly of the left pulmonary vein, in which the venous drainage from the upper lobe of the left lung is emptied into the innominate vein of the same side near the angulus venosus, was studied by Mr. R. Jack and Mr. Henry Lee in connection with their work in the dissecting room. They explain the anomaly on the basis of persistence of embryonic anastomoses.

TECHNIQUE OF MEASURING FETUSES

During the past ten years, as the reader of these reports will know, Dr. A. H. Schultz has been engaged in a metrical study of the preserved bodies of human fetuses and Primates in general. From this experience he has been able to formulate a technique of measuring that can be applied equally well to all Primates, and to all stages of growth from early fetal to adult life. He has recently prepared a detailed description of his technique and methods of measuring so that his own results will be clearly understandable and available for exact comparison for other investigators. It is also hoped that it may prove useful as a guide to those who have access to new primate material and particularly to fetuses of different human races.

The element of comparability is fundamental in measuring. Therefore those measurements are important that are representative for a particular morphological unit and as such can be taken in a strictly corresponding manner in different specimens. Further, only such measurements should be chosen that can be determined in an accurate unequivocal manner. Finally, no matter how carefully a measurement may have been selected, and regardless of the clearest definition of the technique employed, it is not likely to be valuable for comparison unless it is generally adopted by the investigators upon whose cooperation the accumulation of comparable data depends. The degree to which Dr. Schultz has met this plurality of factors promises well for the usefulness of his assembly of technique. Therein, he has made one of the important steps in our search for the laws of growth and variation in the human body.

DEPARTMENT OF GENETICS¹

C. B. DAVENPORT, DIRECTOR

GENERAL STATEMENT

The investigations of the year under review have been fruitful all along the line from chromosomes and genes on the one extreme, to the constitution of race horses and athletes on the other. And between these extremes, observations have not been lacking on the manner in which new genes arise, and how the genes do their work directly through the control of growth and development and indirectly by means of the endocrine glands.

The structure of the chromosomes has become elucidated by the observations of Belling, who concludes that chromomeres are already 4-partite genes and that the stainable portion of the chromosome is non-genic material that accumulates over the surface of the genes at a particular stage in nuclear activity. He also sees the phenomenon of crossing-over, not as a casual but as a regular one. An interchange of segments takes place also between non-homologous chromosomes, and results in characteristic irregular unions of chromosomes and peculiar linkage in inheritance.

Additional light has been thrown on the mutation of these genes; a mutation which lies at the heart of the evolutionary process, if not of that of development of the individual from the egg. A single gene may mutate in different ways, sometimes in germ-cells only, sometimes in the somatic cells only and sometimes in both somatic and germ-cells. Dimly we are seeing how the process of differentiation in egg development may be generally, as it certainly is in some cases, due to a regularly recurring gene mutation. If this possibility is realized, the sciences of genetics and embryology will be united as, indeed in any case, they are bound to be.

Mutation, as we now see clearly, is one of the great factors of evolution. This is beautifully shown by the results that are occurring in parthenogenetic strains of *Daphnia longispina* which Banta has been following for hundreds of generations. These are "pure lines" in Johannsen's sense, and yet they are mutating repeatedly so that progress has been made in building up a more and more marked head character. The old idea that sexual reproduction—panmixia—is necessary to mutation is gone by this parthenogenetic test also. It seems to be the nature of genes to mutate, though variation in the rate of mutation in different blood lines is very diverse.

The experiments on a parthenogenetic species brought to reproduce sexually throw a new light on the importance of the sexual process. For parthenogenesis permits the accumulation of heterozygous recessive defects and provides no mechanism for getting rid of them. As they accumulate they might weaken the organism in time—perhaps after hundreds of generations. Sexual reproduction brings together chromosomes with the same defective genes. Offspring, so produced, to a large extent die and thus the race is purified. Some of the offspring lose the defect, or defects, altogether, and these constitute the most vigorous and fecund lines. Thus the race is strengthened and revived.

¹ Address; Cold Spring Harbor, Long Island, New York.

While our work has chiefly been, and long must be, with mutations which unassisted nature affords, still we are fortunate to be able to avail ourselves of certain agencies that increase the rate of mutation. That radiations affect development has long been known. It has become in the last decade clear that they affect germ-cells also. In *Datura*, radiations seem to facilitate union of non-homologous chromosomes; in *Drosophila*, they likewise interfere with cell-division at maturation and lead to probable elimination of an X-chromosome from some of the germ-cells. We are finding, as others have, that they affect particular genes.

Important as are the facts of genes as bearers of heredity, there still remains relatively unexplored the great field of control of individual development by the genes. Embryology has to be studied as a physiological process under genetic control. A natural step in this investigation is the study of the growth process and this we have analyzed in mice and in pigeons, to show the part that nutrition and internal chemical factors play.

Sex is another clean-cut character, and to the factors that determine it we have made contributions. While the essential nature of sex is probably one of the, if not the, most fundamental of biological problems, we have not been able to follow up as rapidly as we desire the problem of its chemical basis. The mechanism of control of the sex ratio has been followed in flies, *Cladocera* and rotifers. Also the physiology of the two sexes has been followed in pigeons.

In the field of genetics of special traits we have entered into a cooperative investigation into the nature and hereditary factors of leukemia in mice which it is expected will throw light on this, fortunately comparatively rare but always fatal, disease in man. Inheritance of eye defects and of spotting is being studied also in mice. By appropriate selective breeding, we have produced races of ring doves with large and with small thyroid glands and, parallel with these, studies have been made on families of humans with special tendency to enlarged thyroid in goiterous regions. The extensive research on the measure and inheritance of racing capacity in the thoroughbred horse has reached a point where the main methods of study have been established and it remains to perfect and apply them more widely. Not only will the results of this research be of interest to breeders of thoroughbreds but its methods will be of interest to all students of mammalian genetics.

Strictly human traits whose genetics are being studied are: otosclerosis, athletic ability, sex-linked characters and various mental traits as measured by teachers' marks. Some work is being done also on international standards of measurement of physical and mental traits.

STAFF

The Director has seen through the press the proof of the study on *Race Crossing in Jamaica*; and has, with R. H. Post, completed the manuscript on inheritance in athletes. He has continued the cooperative studies on inheritance of tendency to goiter and on sex-linked traits in man. He has organized the work on interracial psychometry. He presided over the meeting of the International Federation of Eugenical Organizations held at Munich. A. F. Blakeslee, assistant director of the Station for Experimental Evolution, has continued his researches on mutation in *Datura*, with the

assistance of Amos G. Avery, Dr. Dorothy Bergner and Martin J. O'Brien. During the summer of 1929 the same groups were associated with him as last summer. H. H. Laughlin has continued his researches into heredity of the thoroughbred horse and into racial distribution of inventive ability. John Belling has continued his work at Berkeley, California. A. M. Banta and Thelma Wood have carried on the studies in *Cladocera*. Banta was on leave of absence for four months, teaching at Brown University. C. W. Metz, with the aid of Dr. Helen Monosmith and Miss Louise Schmuck, has continued the *Sciara* work.

E. C. MacDowell has worked in association with Dr. Streeter of the Carnegie Institution's Laboratory of Embryology and Dr. M. N. Richter of the College of Physicians and Surgeons, New York. He has been chiefly responsible for the exhibits in Washington in December and at Cold Spring Harbor in May. Dr. Riddle has continued his cooperative research on basal metabolism of ring doves and pigeons with Dr. F. G. Benedict of the Nutrition Laboratory; and Miss G. Christman has served as their technical assistant. Howard J. Banker and A. H. Estabrook have continued their studies on heredity in human families. Estabrook, who has had an unexampled career as field student and showed exceptional ability in the work, resigned at the end of May 1929.

As in previous years, visitors have worked at the Department. Dr. Jar Křiženecký of Brno has studied the relations of the thyroid and thymus to growth in pigeons. Professor D. D. Whitney of the University of Nebraska has worked on sex control in Rotifers.

The President appointed, and the action was ratified by the Executive Committee on January 11, 1929, the following special committee "to undertake a study and submit a report concerning maintenance and extension of research activities of the Institution in the field of eugenics," A. V. Kidder, chairman, Carl C. Brigham, C. B. Davenport, Leslie C. Dunn, H. H. Laughlin, C. E. Seashore, E. L. Thorndike, Clark Wissler. The committee met at Cold Spring Harbor on February 19, 1929, and proposed a program for research on the measurement of human traits.

DETAILED REPORTS ON CURRENT INVESTIGATIONS

THE GERM PLASM

CHROMOMERES AND GENES

During the year progress has been made in the analysis of the visible structural elements of the chromosomes—the mechanism for the internal control of development. The suspicion that this analysis has led to the visible isolation of the gene in favorable plant material has received only support by the later observations of Belling. Moreover, his findings lead to doubt whether the chromatin is the real hereditary substance. Rather is it to be regarded as an extraneous material which tends at a certain stage to accumulate over and around the genes. The iron-brazilin method of bringing out the chromosomes in smear preparations continues to prove highly efficient. The smear preparation of pollen-mother-cells is fixed in chromic-acetic-formaldehyde in the proportions of 1: 10: 16. The latter two ingredients play the most important part in fixation. After washing

out the formalin and treatment with an iron-alum solution the alcoholic solution of brazilin is applied. The cytological details show up well in all phases of meiosis.

Belling adopts as a working hypothesis the view that chromomeres and the 4 chromioles of which each is composed, at a certain stage, are genes, doubtless with more or less of an envelope. This conclusion he enforces with the following parallelism.

CHROMOMERES (AND CHROMIOLES)

Chromomeres are in a linear series in the chromosome at pachyphase.

Chromomeres are formed of two pairs of chromioles at pachyphase.

Chromomeres are of markedly different sizes.

Chromomeres of different sizes have the same order in the two homologous threads at pachyphase.

Only homologous chromomeres of the same sizes are paired at pachyphase.

In rare cases, the two chromioles of one homologue seem smaller than those of the other.

Homologous chromomeres attract one another, and are joined by thin threads.

All chromioles divide at the same rate.

The number of ultimate chromomeres has been shown, in four plants, to be probably between 1,500 and 2,500.

GENES

Genes are in a linear series in the genetic chromosome.

Genes are divided into two pairs at pachyphase.

Genes are of markedly different qualities.

Genes of different qualities have the same order in the two homologous genetic chromosomes.

Only genes of identical qualities are paired in homozygotes.

Rarely the homologous genes differ in quality, being allelomorphic.

Homologous genes attract one another and pair.

All genes divide at the same rate.

The number of genes has not yet apparently been shown to be outside these limits.

A study of the distance between chromomeres in *Lilium* has led Belling to the conclusion that in the formation of the pachyphase, or thick "chromosomes" at late metaphase, the chain of chromomeres not only becomes shortened by approximation of the chromomeres but also by a zigzagging of the chain itself. The chain thus becomes thicker and shorter. Since the shortened thread still lies in one plane its splitting is easily possible. The zigzagging is visible as an external corrugation in the phase of greatest thickening of the chromosome and immediately before and after.

Belling has found that the total volume of the bivalent chromosomes increases many times at the stage of maximum size by accumulation about them of additional chromatin. As the chromosomes are about to divide, two-thirds of their chromatin becomes dispersed. From this behavior Belling draws the conclusion stated above, that chromatin is not the basis of inheritance, but a stuff that comes gradually to envelop the essential genes with a progressively thicker coat up to a maximum at anaphase.

Belling has recorded (Nature, No. 3084) the behavior of the chromioles that arise by splitting of each of the paired chromomeres and form tetrads. He has made observations also on the formation of nodes and internodes in chromosomes at the diplophase or beginning separation of the chromosomes, preparatory to cell-division. Homologous chromosomes remain for some time in contact at 1, 2, 3, or even 4 nodal points, not by wrapping around each other like the stripes of a barber pole but by contacts in a single plane. "The occurrence of a node or chiasma," says Belling, "has no other explanation than that of a previous segmental interchange between chromosomes." The numbers of chiasmata in *Hyacinthus* and in *Lilium* have been shown by Belling to be not far from the number required to agree with the genetic results in *Drosophila*.

Segmental interchange between non-homologous chromosomes results not in chiasmata but rings or chains as in *Oenothera*, *Tradescantia*, *Rhoeo*, etc.

CHROMIOLES IN TRIPLOIDS

Belling has investigated the arrangement of chromomeres (each made up of 2 sister chromioles) in triploid hyacinths at zygothase. In such triploids the three threads form a more or less trihedral filament, along which the homologous chromomeres are connected in the transverse plane to form triangles. These triangles are constituted of threads uniting the apically situated chromomeres.

MUTATIONS

MUTABLE GENES IN DROSOPHILA

In continuation of his studies on mutable genes in *Drosophila virilis*, Demerec has concentrated on a study of the mutable wing-character called "miniature." As stated in previous reports mutable miniature reverts (mutates) frequently to its wild-type allelomorph, and these reversions occur both in germ-cells and in somatic cells. Dr. Demerec reports further as follows:

"It has been found previously that the mutability of miniature could be stimulated by genetic factors. Two of them were isolated: factors S-1 which stimulates the mutability of miniature in the somatic cells and factor M which stimulates the mutability in the germ-cells. During the past year tests were made with the 31 stock cultures available in the laboratory to determine whether any of them contained factors affecting the mutability of miniature-alpha. In addition to the already known factor S-1, two more factors stimulating somatic mutability were isolated: a recessive s-2 factor and a dominant S-3 factor. Mutable miniature in the presence of homozygous s-2 or homozygous or heterozygous S-3 gives almost one hundred per cent flies mosaic for miniature and wild type. In these flies miniature reverted to wild type during the somatic development."

CHANGES OF MUTABLE MINIATURE GENE

"The mutable miniature character was derived from a single miniature male found during the winter of 1925. The first miniature offspring of that male was mutable both in the germ-cells and in the somatic cells. During the past year, however, a difference in the type of mutability was noticed in certain miniature lines, and an analysis revealed the following three distinct types of mutable miniature:

"1. miniature-alpha type in which the miniature gene is mutable both in the germ-cells and in the somatic cell,

"2. miniature-beta type in which the miniature-gene is constant, *e.g.* it does not mutate either in the germ-cells nor in the somatic cells, and

"3. miniature-gamma type in which the miniature gene is mutable in the somatic cells but constant in the germ-cells.

"Changes in both directions from miniature-alpha to miniature-gamma type and from miniature-beta to miniature-gamma type were observed. They occur with a relatively low frequency (once to several times in one thousand individuals). No change either from miniature-beta to miniature-alpha nor in the reverse direction has been noticed, but no extensive experiments were made to detect these changes. The gene determining mutable miniature character, therefore, is in an unstable condition changing frequently in several directions, namely to a stable wild-type gene and also to unstable miniature genes of various degrees of instability (fig. 1). What

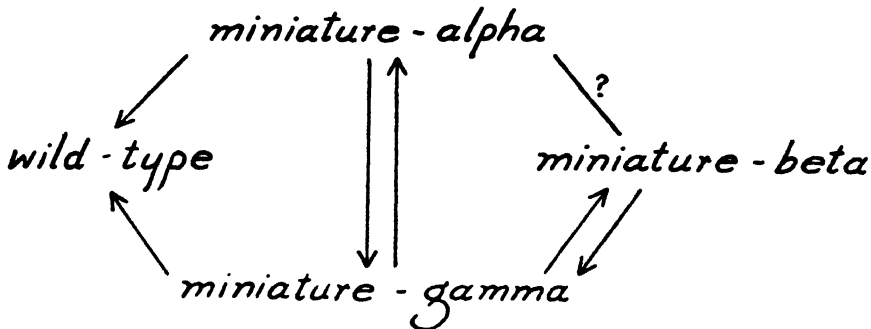


FIG. 1—Changes occurring in mutable miniature gene.

is responsible for the instability of the miniature gene and for the instability of other similar genes? Is that instability caused by an unstable chemical composition of the gene, by its complex physical structure or by some other unknown agent? It would be just a guess to try to answer these questions at present. It is up to the future experiments to supply the material for the answer."

SIMILARITY BETWEEN THE BEHAVIOR OF MINIATURE-GAMMA GENE AND THAT OF CERTAIN TYPES OF SPOTTING IN MAMMALS

"As already mentioned, the miniature-gamma gene is mutable in the somatic cells but it is constant in the germ-cells. The miniature wings of the flies having that gene are covered with various sized spots of the wild type tissue but an entirely wild type individual is never found. The frequency and the size of these spots in a miniature-gamma line could be greatly modified by certain other genetic factors (S1, s2 and S3). The behavior of miniature-gamma character, therefore, approximates closely the

behavior of certain types of spotting in mammals and suggests a possibility of a new explanation of the origin of such spotting."

A MUTABILITY-REDUCING GENE IN DELPHINIUM

While all genes that affect mutability in *Drosophila* stimulate that mutability—

"In *Delphinium* a gene has been discovered which has the opposite effect, namely, it reduces the frequency of mutability of the rose-flower color gene. This mutability reducer is a dominant factor and when present with the mutable rose gene it reduces the frequency of mutability of that gene to about one-tenth of the original frequency. The evidence for the inheritance of the mutability reducer is presented in Table 1.

TABLE 1—Data on inheritance of mutability reducer

Constitution of parents—	Mutability of offspring			
	Observed		Expected	
	Low	Medium	Low	Medium
Reducer homozygous recessive, selfed.....	.....	94	.....	94
Reducer homozygous recessive × homos. dominant.....	21	.....	21	.....
Reducer heterozygous recessive × homos. dominant.....	45	1	46	.....
Reducer heterozygous self pollinated.....	50	15	48.75	16.25
Reducer heterozygous × heterozygous.....	53	15	51	17
Reducer heteroz. × homos. recessive.....	31	41	36	36

"The effect of the mutability reducer on the mutability of the rose gene is being closely studied. Observations were made on the area of the sepals and the number of mutations (purple spots) which occurred on them. Areas in square millimeters were multiplied by 800, which was found to be an approximate number of cells per one square millimeter and an estimate of the number of cells for each observed sepal was obtained. From the total number of cells involved and the number of observed mutations, the frequency of mutability per one million of cells was calculated. Preliminary counts indicated that in the material studied the rose gene with recessive mutability reducer mutated 818.40 times in one million cells, and the same gene with the dominant reducer mutated only 80.99 times in one million cells."

Additional genes effecting flower color in *Delphinium* have been investigated by Demerec. Thus there has been found a recessive allelomorph of the mutable lavender flower-color character. This makes it possible to study the mutability of a single lavender gene, which will be an advantage in many experiments. Also, it has been found that the lilac flower-color character is closely linked with or is an allelomorph of the mutable rose flower-color character. This discovery will shorten many experiments and save a great deal of labor, by making it possible to distinguish, without further breeding, homozygous from heterozygous mutable rose flower plants.

CHROMOSOMAL MUTATIONS IN DATURA

The jimson weed still yields new somatic types associated with chromosomal aberrations. In the year under review two new secondaries (extra chromosomes compounded of like halves of 2 homologous chromosomes) have been identified. We have now at least one secondary for each of the 12 primaries, except the 3 that involve the smallest chromosomes. In addition, for 3 of the primaries (Rolled, Buckling and Echinus) we have both complementary secondaries. Dr. Blakeslee and his group have found also a dozen or more tertiary types in which the extra chromosome is composed of parts of two non-homologous chromosomes. Blakeslee reports:

"Among these tertiaries are a number of compensating 25-chromosome types characterized by the possession of two abnormal chromosomes, parts from each of which together furnish a full complement of genes of a normal chromosome, while the remaining portions of the two bring about the peculiarities of the affected plants. Moreover, types are known in which the extra chromosomal material consists of a single fragment.

"The study of cryptic chromosomal types has been extended with the cooperation of Dr. Bergner, who has been in charge of this phase of the work, Miss Satin, Dr. Simpson, Miss Johanson and Miss Chambers. Accordingly, it is now possible, after cytological study of over 225 races, to say something about their distribution in nature. The Line 1 type, which in the hybrids with our standard race shows 12 closed bivalent chromosomes at reduction, appears to be the commonest type in the United States and in Brazil. Elsewhere the B type, which in F_1 's with Line 1 induces a ring of 4 attached chromosomes involving chromosomes L and m, is most frequent. Most of the races from the west coast of South America induce in hybrids a circle of 4 small chromosomes in addition to the circle of the B type. The origin of types which induce circles can best be explained on Belling's hypothesis of segmental interchange between non-homologous chromosomes.

"Certain other races induce the formation of chains of 4 or 6 attached chromosomes instead of closed circles. The possibility that translocations have been responsible for the origin of such races is being investigated. Races inducing such chromosomal types, as well as circles, should be of ultimate value in an analysis of chromosomal differences between species.

"From a hybrid between our standard line and one of our cryptic types we have isolated a new morphologically distinct pure-breeding type with one pair of chromosomes showing an attached fragment."

GENE MUTATIONS IN DATURA

The prolonged search for new gene characters is yielding new labels or tags of the chromosomes of the jimson weed. The number of genes thus located is 15 and there are perhaps as many not yet located. The latter include some which give poor viability to the individuals affected. Blakeslee reports:

"We have located 3 genes in each of 4 different chromosomes. In *Poinsettia* the genes for curled and wilt are in the dwarf half and the gene for white flower-color is in the opposite half. These 3 factors form a linkage group and their positions in it are not inconsistent with their locations by trisomic ratios.

"In the Glossy chromosome the factors for bronze (leaf), nodal spot and ferox-white are either very closely linked or form a multiple allelomorph

series. Ferox-white is a recessive factor for white flower color that has been extracted from *Datura ferox*. When crossed with bronze, which is dominant, the gene for ferox-white inhibits the expression of the bronze character.

"Crossing-over between the factors for white and curled in the circle of 4 in hybrids between B-races and our standard Line 1 type has been studied. The cytological and breeding behaviors suggest crossing-over between the chromosomes that go to make up the circle but the results might be brought about by a return interchange, although the latter process seems an unlikely explanation. Since Nubbin has only one intact L chromosome it is possible, by rendering Nubbin heterozygous for Line 1 purple and a B white, to distinguish between crossing-over and return selection and to determine that crossing-over is the cause of the exceptional dominant diploid individuals produced by back-crossing a heterozygous Nubbin to the recessive white."

EXTENSION OF FINDINGS IN DATURA TO INTERPRETATION OF OENOTHERA PROBLEMS

In cooperation with Dr. Cleland of Goucher College, Blakeslee, basing conclusions on the experience with Datura has contributed to the hypothesis that the remarkable configuration of the chromosomes in *Oenothera* (forming circles of from 4 to 14 chromosomes at reduction) are to be explained on the ground of segmental interchanges and translocations between non-homologous chromosomes. They read a joint paper on the subject in April 1929 before the American Philosophical Society.

MUTATIONS IN PARTHENOGENETIC CLADOCERA

EXCAVATED HEAD CHARACTER

Banta has continued the strain of *Daphnia longispina* that shows a peculiar modification in the form of the head—called excavated head. By selective breeding he has secured a line that shows the character in high degree and another that shows it in low degree; and the degree of expression has been progressively increased by breeding the mutations that nature has afforded. From the varied grades of expression of the character the inference was drawn that at least 6 and possibly 8 factors are involved in the maximum expression that has been obtained of the excavated head. Presumably 4 or 5 of these factors were involved in the expression of this character as first observed.

"Selection in the original sister strains was in most cases more promptly effective when made in a 'low' direction, though it was ultimately effective in the 'high' direction too. Selection in the high direction in the two lines, in which this selection was long continued and was most successful, apparently 'picked up' two (more probably three) additional mutations whose effect together was to increase the manifestation of the character to twice or more than twice that originally observed. Selection in the low direction has, in the most successful cases, 'dropped out' four of the five factors for excavated head originally present. Such selected low strains bear the character very slightly indeed (as numerically represented, less than one twenty-fifth of its original expression) and might very readily be mistaken for normal (i.e. non-excavated head) strains."

Return selections were attempted with both the selected high and selected low strains. The latter have been continued for 70 generations. In return selections, also, the attempts to increase the character were less effective

than those to decrease it. Indeed, attempts to increase the character from the low strain have failed; but the same strain has by low selection been brought lower. Selection toward low is more effective than selection toward high.

This greater facility for exaggerating a character in a minus more than in a plus direction is found in the sex-intergrade series also. Apparently head form and secondary sex characters are determined by a number of genes or genomeres. It is easier to find strains which have lost one or more of these units than those which have gained them.

ACCUMULATION OF RECESSIVE MUTATIONS UNDER COVER OF PARTHENOGENESIS

New light has been thrown by Banta's experiments of the past two or three years upon the accumulation of recessive lethals following parthenogenesis and their partial elimination following sexual reproduction in previously parthenogenetic strains.

While within a (parthenogenetic) clone the reproductive vigor is, in general, remarkably constant, occasionally a change occurs in reproductive capacity. Such a change, because of its sudden appearance and its persistence in successive parthenogenetic generations, we must regard as a mutation and, indeed, a dominant mutation; else it would scarcely be manifest in diploid parthenogenesis.

On the other hand, as pointed out in last year's report, recessive mutations are to be expected more frequently than dominant ones; and experiments in sexual reproduction in *Cladocera* indicate that such is the case. Without sexual reproduction such recessive mutations would not be obvious unless by rare chance they were duplex. They might accumulate within a clone during a long period of parthenogenetic reproduction. Young derived from sexual reproduction in or between such clones show marked and inheritable differences in viability, fertility and other physiological characteristics.

To the time of report, the results of inbreeding by sexual reproduction in *Daphnia longispina* show that while Line XI (see Year Book 27, p. 46), after 356 parthenogenetic generations hatched 11 per cent of its sexual eggs, that line after 390 parthenogenetic generations produced no hatchable eggs. In contrast to this is the 47 per cent hatchability of Lines 1621 and 1622 with brief parthenogenetic history.

When two clones that have a long parthenogenetic history are crossed, hatchability is low (10 per cent); while if a long-parthenogenetic strain is mated to a short-parthenogenetic strain the fertility is fairly high—about 50 per cent.

Sexual reproduction, especially inbreeding, tends to bring to the surface recessive defects that affect reproductivity and development. The vigorous progeny of such inbreeding, purified of their defects and homozygous for developmental vigor, may well show developmental capacity above the average.

GENETICS OF THE THERMAL CLONE

There have been new developments in the thermal clone whose discovery was described in Year Book No. 26 (p. 54). This strain originated from

inbreeding Strain XI, in which the factor (or factors) for thermalness had presumably already appeared as a recessive mutation. Of the 7 sexually produced clones obtained by this inbreeding, one alone (B 9) was, on this hypothesis, homozygous for this factor and hence was thermal.

To test this hypothesis it was desired to inbreed B 9. Certain difficulties were encountered. First, B 9, though unusually vigorous, when inbred produces very poor hatches (7 per cent) and only a small proportion (18 per cent) of the hatched individuals were viable and fertile. Even the fertile individuals produce very few young. It is difficult to maintain these clones (T M's) derived from the inbred B 9. Second, the thermal clone, B 9, has apparently in some of its branches partially reverted to the normal condition of resistance to low temperatures. Originally B 9 was remarkably vigorous at 27° C. but was unable to reproduce at 20° C. or lower; and all the young died at below 21° C. Recently this strain is viable and vigorous at 20° C., or even lower. As this clone was being kept at 27° C. and had not frequently been tested for resistance to 20°, the time at which the reverse mutation occurred can not be precisely told.

To test the thermal characteristics of B 9 and the clone (T M 10) derived by inbreeding B 9, their reaction to 40° C. was compared with that of the "normal" Strains XI and B 3. The comparison was made with females that had just released their first clutch of young and which had been reared at 27° C. Such females of each pedigree were grouped with similar and equal lots and subjected to a temperature of 40° C.—one lot for 10 seconds, a second lot for 20 seconds and so up to 100 seconds. There was thus determined the time required at 40° C. to kill 50 per cent of the individuals. In Strain XI this was 50 seconds; in Strain B 3, 50 to 60 seconds; in Strain B 9, 80 seconds; in T M 10, 100 seconds. Clearly B 9 and its sexual descendant clone T M 10 possess a superior heat tolerance, though the superiority in the case of B 9 is less well marked than formerly.

PHYSIOLOGICAL STUDIES ON THERMAL CLONES

Under Banta's direction, Miss Thelma Wood is measuring the oxygen consumption of several clones of *Daphnia longispina*. For this purpose is used a modification of Fenn's adaptation of Krogh's manometer, utilizing the movement of a kerosene droplet in a capillary tube as a measure of oxygen consumption. Even in this very sensitive apparatus it is necessary to run 10 animals at a time. Only vigorous animals reared under identical conditions are used and all are tested soon after having released their first clutch of parthenogenetic young.

Of the strains used B 9 (the thermal clone that arose as one of the sexual offspring from inbreeding Strain XI) is exceptionally vigorous. It reaches reproductive maturity earlier than the others and produces larger clutches of young. It has an oxygen consumption of 8.2 mm. (read as movement of the kerosene droplet in the capillary tube of the manometer) per hour per 10 individuals.

B 3, which is a non-thermal sister clone of B 9, is of a little less than average vigor and is intermediate both as regards time of attainment of sexual maturity and size of clutches. It has an oxygen consumption of 6.5 mm., per hour per 10 individuals.

T M 10 is a weak strain derived from inbreeding B 9. It is slow in reaching reproductive maturity and produces very small clutches. It has an oxygen consumption of 4.1 mm., per hour per 10 individuals.

Strain XI, the parent clone from which the above-mentioned clones were derived, is somewhat below the average in rate of development and reproductive capacity. Its rate of oxygen consumption is about 5 mm. per hour per 10 individuals.

Though the figures given above are preliminary only and additional data are being collected, they do suggest a clean-cut association between reproductive capacity and rate of oxygen consumption.

The above work of Miss Wood is patterned largely upon that of Dr. V. Obreshkove of St. Stephen's College (Columbia University), who has studied here the rate of oxygen consumption of 3 clones of *Simocephalus exspinosus* which had originated from a common stem mother and subsequently passed through long periods of parthenogenesis. Two of these clones presumably underwent dominant mutations that reduced their reproductive capacity. These two strains, when tested by a modified Krogh manometer, showed a rate of oxygen consumption less than half that of the vigorous sister clone with which they were compared. These results, now ready for publication, represent, says Banta, "an important contribution both to the genetics of physiology and the physiology of genetics."

EXPERIMENTAL MODIFICATION OF THE GERM-PLASM

This division of our work has been especially fruitful during the year under review.

DATURA

Blakeslee has extended his analysis of genetic changes in *Datura* following radium treatment. He reports as follows:

"Out of 51 F_1 plants from radium treated parents, 7 chromosomal abnormalities (14 per 100 plants) were discovered by Dr. Bergner and Miss Satin. The chromosomal abnormalities include deficiencies for a whole or a part of a chromosome, alterations (probably interchanges) causing the formation of closed circles of 4 or 6 attached chromosomes, and fragmentations and reattachment of the fragments to non-homologous chromosomes or parts of chromosomes, bringing about chains of 4 members. Information in regard to the specific chromosomes involved in these changes is being obtained from cytological study of their sizes, from their attachments especially in $(2n+1)$ types, and from the morphological effects which they bring about when the modified chromosomes are present as extras.

"Of especial interest is a change induced in the largest (L) chromosome which was apparently fragmented into its two halves. It may be remembered that the L chromosome when extra produces the primary $(2n+1)$ type Rolled and that one half doubled forms the extra for the secondary type Sugarloaf and the other half doubled as an extra forms the complementary secondary Polycarpic. In the change under discussion, the Polycarpic half of the L chromosome remained as a fragment, while the Sugarloaf half became translocated to a large median (M) chromosome resulting in a chain of 4 attached chromosomes consisting of 3 large and 1 small median chromosome. By selfing such a plant, which is normal in appearance, an F_2 population was obtained consisting of 3 individuals normal in

appearance to 1 resembling the Secondary Sugarloaf but with the Sugarloaf characters less strongly expressed. The normal-appearing individuals were of 3 types: (a) those with only normal chromosomes; (b) those like the F_1 , with the Sugarloaf translocation and the Polycarpic fragment; and (c) those homozygous for both the Sugarloaf translocation and the Polycarpic fragment. Three kinds of Sugarloaf-like individuals were also to be expected: (a) those with a single Sugarloaf translocation; (b) those with two Sugarloaf translocations and a single Polycarpic fragment; and (c) those homozygous for the Sugarloaf translocation but without the Polycarpic fragment. The Sugarloaf-like types *a* and *b* have been identified in the F_2 but, probably on account of the small numbers, the type *c* was secured first in a later generation. Thus, by selfing the Sugarloaf-like types in F_2 , we have obtained an F_3 with 3 Sugarloaf-like types to 1 normal. In this generation some of the Sugarloaf-like individuals were as distinct as the secondaries of this name and were found to be homozygous for the attached fragment. They contain two normal L chromosomes and two M's with the attached Sugarloaf fragments. These chromosomes sometimes pair and sometimes form a closed circle of 4 members. As was to have been expected, they breed true and, so far as their chromosomes have been examined in F_4 (5 individuals), show circles of four at reduction. We have thus established a morphologically distinct pure breeding race by translocation of a chromosomal fragment. The races in our collection, especially those which induce chains of 4 or 6 chromosomes in hybrids with our standard line, are being studied to see if a similar phenomenon has been effective in the differentiation of races in nature.

"Nubbin, a type obtained following radium treatment by Dr. Gager in 1921 in which 3 chromosomes were fragmented and the fragments of one were attached each to a fragment of the other two, has been of considerable service in the analysis of the cryptic types in nature. It is believed that the new types we are obtaining following the radium treatment by Dr. Buchholz will be of similar service and aid in our study of the architecture of the chromosomes.

"In addition to visible changes in the chromosomes, the following abnormalities have appeared following radium treatment: definite proportions of aborted pollen determined chiefly by Dr. Cartledge; abnormalities in pollen-tube growth determined by Dr. Buchholz, including non-germination of half the pollen grains, bursting of half the pollen tubes and bimodal curves of pollen-tube growth. Visible gene effects of radium treatment have not as yet been common in *Datura*."

DROSOPHILA

INDUCTION OF NEW MUTATIONS

Demerec has for some years been on the lookout for new mutations in *Drosophila melanogaster*, since in his early experiments such new mutations in *D. virilis* were found to be especially mutable. He has used the X-ray treatment to induce such mutations. From the rayed material 21 good mutants were obtained, but none was mutable.

EFFECT OF X-RAYS ON NON-DISJUNCTION OF X-CHROMOSOMES IN *D. VIRILIS*

Demerec reports on this experiment as follows:

"It is known that the X-rays increase the frequency of primary non-disjunction in *Drosophila melanogaster*. Available data indicate that the effect of the X-rays does not change the normal proportion between the

non-disjunctional males and females. It was found that in *Drosophila virilis*, as well as in *Drosophila melanogaster*, X-rays increase the number of primary non-disjunctions and, in addition, preliminary experiments indicate that the proportion between the males and females is appreciably changed in favor of males, as can be seen from the data of Table 2. The

TABLE 2—Primary non-disjunctions in *Drosophila virilis*

Parents	Offspring			
	Regular		Exceptional	
	♀	♂	♀	♂
Not treated.....	14182	11851	15	21
Mothers X-rayed.....	4211	3731	4	54

deficiency of primary females is interpreted as being caused by one of the X-chromosomes lagging at the reduction division and its being finally eliminated from the germ-cells. The available data indicate that the X-ray treatment increases this lagging and elimination of one of the X-chromosomes of *Drosophila virilis*. It does not have any significant effect on elimination of X-chromosomes of *Drosophila melanogaster*."

DEVELOPMENT AND ITS GENETIC AND NUTRITIONAL CONTROL

GROWTH IN MICE

For the third year progress can be reported on the experiments of MacDowell on the isolation of the genetic and the nutritional factors in the growth of mice. With him in this work have been associated Mrs. MacDowell and Miss Jean M. Marsh. A school had arisen that attributed irregularities in the curve of growth to a succession of innate growth activators. MacDowell has investigated the nature of the limitations to the growth rate. He reports as follows:

"In order to study internal limitations to growth rate it is necessary to remove external limiting factors by experimental means. In the report of 1928 the conclusion was given that the early growth of the mouse is normally limited by external conditions; that by increasing the opportunity to obtain mothers' milk, the inflection point in the growth curve was shifted from the seventh to the eleventh day. In the past year this conclusion has been given even further foundation by delaying the inflection point another four days. By improved technique, mice may be raised for 14 days before reaching the inflection point in their growth curves. At this time they are more than twice as heavy (15 grams) as mice raised in full litters. Up to this point the curves resemble the curve for prenatal growth in that both are parabolic. On the fifteenth day appears a sharp break, which clearly indicates the sudden effectiveness of new influences.

"The 15-day break is a distinct phenomenon available for experimental analysis. Experiments have already shown that the limitation responsible for this break is of a different nature from that acting on the earlier stages; the problem has been narrowed down and the direction of further work has been indicated.

"This break is not due to a diminution in the mother's milk supply at 15 days after parturition, as (1) the break occurs at the same time when foster mothers 5 days nearer parturition are used. (2) The possible return of œstrus at this time does not limit the production of milk. Mothers whose ovaries were removed on the day of parturition gave the same results as normal mothers. (3) In order to provide an unlimited supply of milk the experiment was carried out of using rats as foster mothers. This was successful to the extent that the rats accepted the baby mice and nursed them well, but the daily increments of growth were not so regular as with mouse mothers and there was no suggestion of any postponement of the 15-day break. The irregularity in the increments may be accounted for by various factors, such as the dissatisfaction of the rat mothers with strange quarters, and unsuccessful nest boxes, resulting in the babies being continually scattered about the pen. Subsequent experiments have given such clear answers to the main question at issue, that this rat-fostering experiment has not been repeated with improved technique. This conclusion has been more dramatically confirmed (4) by experiments in which four new-born young were given to a mother in the third week after parturition, after her own young, raised under the special conditions, had passed the 15-day break. Such mothers gave the second litters considerably more milk than they gave the first one. That is, the total amount of baby mouse produced in the third and fourth weeks after parturition was strikingly greater than the amount produced in the first two weeks. The second litter was not reduced below four young so that the amount of stimulation of the mammary gland was greater and the average weight of the individuals was less than in the case of the first litter which was reduced to one.

"If the quantity of milk available does not account for the break at 15 days, attention becomes focused upon the young themselves. So far as it is due to the stage of development of the young, the control may be classified as innate, but the deeper question still remains. Is this a phenomenon of the fundamental growth process or is it due to a change in the acquisition or use of nutrition? This introduces the first step in the recognition of different degrees of limitation; a separation of primary growth processes taking place within the tissues of the animal, from changes in the functioning of the animal as a machine, which latter changes result in new food habits and needs. In attempting to obtain a knowledge of the nature of growth, the limitations of the last category must be considered secondary. They mask the essential growth processes as effectively as purely external conditions. Only by the experimental removal of these masking conditions can the nature of the primary growth factors be revealed.

"There is a close correlation between the 15-day break, a change in the character of activity, the first eating of solid food and a falling off in the mother's appetite. The amount the mother eats is highly correlated with the amount of milk that is taken by the young. In the experiments in which new-born mice were given to the mothers which had already raised one young to 15 days, the amount of food eaten by the mothers immediately rose in proportion to the increments of the babies' growth; when the young were removed the mother's food total dropped immediately. Taken together with the evidence previously cited, these results fairly well eliminate the mother as primarily responsible for the break. The falling off in her eating is a result not a cause of the break.

"The possibility that the first eating of solid food causes a temporary reaction in the digestive system which holds back growth has been eliminated by a series of experiments in which mothers were fed at regular inter-

vals away from the young in special food boxes so there was no possibility of the young ever touching solid food. The 15-day break occurred as regularly as when food was present all the time. But instead of the sharp upward turn of the curve that normally follows, the depression continued, showing either a gentle rise in the curve, maintenance, or actual steady loss. With the introduction of the full diet comes an immediate leap in the curve. This situation seems to point to a diet deficiency as a possible primary factor and opens the way for critical diet experiments. On the other hand the possibility must be recognized that the dawning of adult behavior may be the primary factor and that a reduction in the quantity of milk taken is the immediate cause of the break. In either case the phenomena reported are open to experimental testing. Should either of these suggestions prove to be correct, the break would be shown to be independent of fundamental growth processes.

"The conclusion is well established that the outstanding changes in the growth rate of the mouse coincide with major changes in the conditions of life and, so far, the analysis offers no evidence that the fundamental, innate growth processes determine the so-called cycles into which the growth curve has been dissected by certain authors."

GROWTH IN PIGEONS

In association with Riddle, Dr. J. Křiženecký of Brno, a Fellow of the International Education Board, has been conducting studies on some relations of thyroid and thymus to growth in pigeons. In one of these studies he has continued his earlier investigations on the protective influence of the thymus against the retarding effects of hyperthyroidism on body growth and on feather growth.

In another study he has found and followed the histological changes of the thyroid gland throughout the reproductive cycle of the pigeon. This important contribution will extend our knowledge of the share of the thyroid in the processes of reproduction, and it materially adds to what this department has earlier done toward the elucidation of endocrine changes which accompany the process of ovulation. Dr. Křiženecký's studies are being continued; further report on them must be deferred to next year.

SEX STUDIES

ESSENTIAL DIFFERENCE BETWEEN SEXES

Through the generosity of Mrs. George S. Franklin, Mrs. W. B. James and Mr. Walter Jennings, neighbors, we have been able to retain the services of Miss Satina and make additional observations in this field while awaiting a possible development of the topic on a scale worthy of its importance.

SEX RATIOS

SCIARA

For some years Metz has been seeking a cytological interpretation of the remarkable sex ratios shown in the fly *Sciara*. These studies have been aided by a grant from the National Research Council, providing for the assistance of Miss Louise Schmuck. Dr. Helen Monosmith has participated in this research. Metz reports as follows:

"Six main results have been secured during the year, which serve materially to advance our understanding of chromosome behavior and genetic

behavior in *Sciara*. If our present interpretation of these results is correct, we are presented here with a complicated and novel type of sex determination involving elements of whose origin it is very difficult to conceive. Most conspicuous among these is the process which appears to involve selective fertilization through a selective elimination of male gametes. While the present interpretation of these features appears to be warranted by the data (published or in press) it is to be recognized that many peculiarities in these flies remain to be cleared up, and that as the study progresses a revision of the interpretations may be required.

"The 'male-limited' chromosomes"—One puzzling characteristic of *Sciara*, as noted in previous reports, is the presence in males of two large chromosomes not found in females. Examination of eight species, representing different sections of the genus, indicated the general presence of these chromosomes throughout the genus. Recently, however, we have found that in one species (or at least in the strains we have used) these large chromosomes are absent from the spermatocytes, and hence presumably from the other cells as well. The other cytological peculiarities of the genus (monocentric mitosis, etc., previously reported) are, however, present.

"This finding indicates that the large 'male-limited' chromosomes are not sex-determining, although they exhibit characteristics of behavior typical of sex chromosomes. The latter fact, together with other features discussed elsewhere, suggests that these chromosomes may have descended from true sex chromosomes and that present conditions represent an evolutionary stage in the transference of the sex-determining function from one pair of chromosomes to another. An alternative interpretation is that they are modified Y-chromosomes; but since a typical Y-chromosome is present this seems untenable.

"Basic sex-chromosome constitution of males and females"—Coincident with the cytological observations mentioned above, genetic experiments on *S. coprophila* have shown two new mutant characters to exhibit sex-linked inheritance of the type found where the female is homogametic and the male heterogametic. On the basis of this evidence it is assumed that sex chromosomes of the indicated type are present (XX female, XY male). The presence of Y in the male is inferred from the chromosome number although the Y has not been identified by any size difference.

"The above finding agrees with the evidence given above in showing that the large 'male-limited' chromosomes are not essentially concerned with sex determination. It is primarily of interest, however, as indicating that the male is heterogametic and that the sperms are 'sex determining.' This does not harmonize readily with the fact that 'unisexual' progenies are produced and that it is the *female* which is responsible for the sex of the progeny as a whole, as previously reported.

"Sex chromosomes and 'unisexual' progenies"—In last year's report a scheme of inheritance underlying the production of 'unisexual' progenies was presented. It was noted that the sex of the progeny is determined by the mother and that in each female progeny half the females are female-producers and half male-producers. The inheritance follows a simple scheme in which the female-producing female appears as *Aa*, the male-producing female *aa* and the male *aa*, the symbols *Aa* or *aa* representing pairs of genes or of chromosomes.

"During the present year it has been shown not only that the above scheme is essentially correct but that it is the sex chromosome pair which is responsible here. The sex of the 'progeny as a whole,' therefore, is dependent on the same pair of chromosomes as the sex of the individual fly.

Much of our recent work has been devoted to an analysis of these features and to an attempt to bring them into harmony with the other lines of evidence here. One of the first conclusions required is that the two types of females differ in their sex-chromosome constitution, and that the two sex chromosomes of the female-producing female are not entirely alike. On this basis figure 2 has been outlined to represent the mode of inheritance observed. As indicated, the male-producing female is homozygous and homogametic as regards sex chromosomes. The male and the female-producing female are both heterozygous and heterogametic in this sense.

"Interest attaches especially to the constitution of the female-producing female. Genetic evidence shows that one of her sex chromosomes (X) is the same as those of the male-producing female, but that the other (X') is different. Whether this difference involves only one pair of genes or extends to more of the chromosome is not known; but the latter is suggested by the fact that no crossing-over has been detected between X' and X, although extensive tests have been made with the two mutant genes mentioned above. These genes both arose in the X chromosome. They exhibit about 2 per cent of crossing-over in the male-producing female. Thus far we have not succeeded in getting either one into the X' chromosome. This chromosome is not 'empty,' however, like the Y, for it evidently carries the normal allelomorphs of these mutant genes.

"*'Unisexual' progenies due to selective action on gametes*—According to the conclusions outlined above, the male is XY in sex-chromosome constitution and (since individual males give offspring of both sexes) produces two kinds of sperms, X-bearing and Y-bearing, the former being 'female-determining' and the latter 'male-determining.' It would be expected, therefore, that pair matings would regularly give offspring of both sexes. On the contrary, as already noted, the progenies are regularly 'unisexual' in the material under consideration, and the sex of the progeny is determined by the female. It is necessary, therefore, to postulate the intervention of some process preventing the production of males in female progenies and of females in male progenies. This might involve a selective mortality of zygotes, such that in one case the males and in the other the females fail to develop, or it might involve a selective action on the sperms, in which in one case the eggs are fertilized only by female-determining (X-bearing) and in the other by male-determining (Y-bearing) sperms.

"*A priori* the former alternative seems the more probable. But careful study has indicated that no such selective mortality of zygotes occurs. This seems to necessitate the conclusion that the selective process acts on the gametes (sperms) even though such a view involves serious theoretical difficulties—particularly that of evolutionary origin. It is hoped that light may be thrown on the latter by a comparative study of related species and by the use of strains giving bisexual progenies.

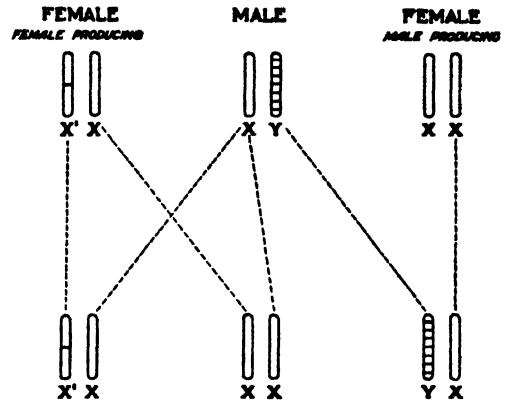


FIG. 2.—Diagram illustrating sex chromosome mechanism and mode of sex determination in *Sciara*.

*"Mode of segregation of sex chromosomes contrasted with that of autosomes, in males—*Another of the most perplexing features of chromosome behavior in *Sciara*, brought out in previous reports, is the selective segregation of certain chromosomes during spermatogenesis, such that only the maternal member of a pair is retained and transmitted by the sperm. This process is characteristic of some (perhaps all) of the autosomes.

"As regards the sex chromosomes (XY), however, it must be concluded from the recent evidence presented above (production of both X-bearing and Y-bearing sperms by each male) that segregation occurs at random, instead of selectively. In other words the pair of chromosomes whose members are known to be unlike, genetically, segregate at random, while those whose members are of like genic composition show selective segregation. This seems of particular significance in supporting our earlier conclusion that the selective behavior is independent of the genic constitution of the chromosome, and is due to something impressed on the chromosome as a whole, or on the non-genic portion, by the sex of the parent from which it came.

*"Origin and behavior of the bisexual strain of S. coprophila—*In last year's report an account was given of experiments with a bisexual strain of *S. impatiens*. Subsequently a similar strain has been secured in *S. coprophila*, which is more favorable for laboratory use. The latter strain was derived from pedigreed stock, and is of particular interest because it is known to have come from a typical 'unisexual' race.

"The bisexual strain is descended from a single 'exceptional' female obtained in a male progeny. According to the above scheme, such a female should be XX in sex-chromosome constitution and hence a male-producer, since she had no opportunity of deriving an X' chromosome from either parent. The genetic behavior of the strain supports this view, since the progenies obtained are typically either bisexual or male. The 'bisexual' characteristic appears to be inherited only through the females, and it has been impossible thus far to secure a pure bisexual strain. When a sex-linked character is introduced its inheritance indicates the presence of an extra sex chromosome in bisexual females, which suggests that the bisexual progenies are due to an extra chromosome. Cytological observations are being made to check this point."

SEX CONTROL IN CLADOCERA

A few additional studies have been made on this topic. Results of the earlier studies are being prepared for publication.

*Critical period of sex control—*First, in last year's report Allen's conclusions were cited to the effect that the maturation division of the egg occurs half an hour before the eggs are laid. This conclusion was based on the fact that clutch sisters of those killed and found to be in the prophase of the maturation division laid their eggs, on the average, half an hour after the moment of killing of those sisters. It now appears that clutch sisters, even under the same cultural treatment, do not lay their eggs simultaneously, but through a range of 2 hours or more. Accordingly the time of the formation of the maturation spindle before egg laying, though short, must be regarded as less precisely known than the earlier statements would imply. Thirty minutes would seem to be a minimum; 90 minutes, perhaps a maximum.

Second, for the control of sex it has been found that the agent is most effectively applied to the medium and hence (to the exterior of the animal) at approximately 240 minutes before the eggs are laid. This is not, however, the interval elapsing between egg-laying and the time at which the sex-controlling agent affects the protoplasm of the ovarian eggs; for it must take some time for the effective agent to reach the ovarian eggs, through the medium of the blood stream or otherwise. These considerations make it probable that the critical period for the internal environment is only a short time before the visible formation of the one maturation division, and strengthens the hypothesis that sex control in *Moina* is brought about by a special arrangement of the sex-chromosome mechanism.

Length of embryonic period for female and male Moina young—Ordinarily within 5 minutes after the young of one clutch are released the mother molts and lays (into the brood chamber) the eggs of the next clutch. By observing a large series of individual mothers at 10-minute intervals it is possible to determine closely the time elapsing between deposit of eggs in the brood chamber and release from that chamber. This is the embryonic period. The young, on release, are sexed and, since the vast majority of broods are unisexual, the lengths of the period of development for female and for male clutches are thus obtained. The average of about 1,750 determinations, made by Banta and Brown, gives an interval that is about 28 minutes longer when the clutch is male than when female. The male embryonic period is nearly half an hour longer than the female.

EFFECT OF CROWDING ON MALE PRODUCTION IN THE ROTIFER, *HYDATINA SENTA*

Dr. David D. Whitney of the University of Nebraska spent several weeks in this Department during the summer of 1928. He carried out a series of crowding experiments on *Hydatina senta*, comparable with those of Banta and Brown on *Cladocera*. In *Hydatina*, females produce ordinarily only female-producers but under certain conditions male-producers are brought forth.

Whitney placed 150 to 200 adult female rotifers in 1 c.c. of culture water, and at the end of 96 hours 1,100 to 1,600 female offspring had been produced and were living in this small quantity of water. They were thus intensely crowded. The young females produced near the end of this period of crowding were isolated and 12 per cent of them were found to produce, parthenogenetically, male offspring, while of the young females from the uncrowded control experiments with 10 c.c. of culture water 48 per cent produced males. Thus crowding of females among rotifers, with its accompanying accumulation of excretory products does not, as in *Cladocera*, induce the production of males and fertilized sexual eggs.

MICE

In tabulating and analyzing the breeding records of the mouse colony, for the years 1924-28, special attention has been given, MacDowell reports, to variations in the sex ratio and to conditions that might influence that ratio. MacDowell finds further:

"The outstanding positive relation discovered depends upon genetic differences and not upon external factors. This appears in the characteristic high ratio shown with great consistency by one strain through the years.

No correlation between sex ratio and season has been found in the colony as a whole; in one strain the per cent males for successive seasons show fairly consistent rises and falls but these changes are not statistically significant. The data have been arranged by periods of different lengths ranging from successive months to half years; by successive seasons throughout the period of years; and by seasons with all years combined; by different definitions of the seasons and by starting months on the first, as well as on the fifteenth day. The constancy of average age of parents throughout the successive seasons shows that any influence of this has been largely eliminated."

SEX DIFFERENTIALS IN PIGEONS: A SEX DIFFERENCE IN THYROID SIZE

In continuation of his prolonged studies on the differences in the endocrines of the sexes in pigeons, Riddle has recently made a report which he summarizes as follows:

"Weights were obtained on the thyroids of 1,917 healthy ring doves and on 602 healthy common pigeons aged 4 to 36 months. Within these age limits there is little or no change in body weight, and in many of the 71 races, or strains, studied there is little or no change in thyroid weight. The large influence of the hereditary factor in thyroid size, and many well-known physiological factors, have here been adequately equalized or controlled; but thyroid weight, nevertheless, shows itself to be highly variable. Mean values obtained from the union of all (71) comparable races of ring doves indicate an excess weight in the females of 4.5 per cent, or of 1.8 per cent. This mean for 19 races of common pigeons is 7.0 per cent.

"Most of the races examined have a characteristic and hereditary size of thyroid which is, in general, reflected in the thyroid weight of both males and females. But, in general, those races which have the smallest thyroids show the smallest percentage sex difference in thyroid size. In races characterized by larger thyroids, the female glands exceed those of the males by a notably higher percentage. We interpret these facts as indicating that many individuals of these races have thyroid enlargements similar to those of endemic goiter; and that, as in the human, the females are more often thus affected than are the males.

"Our average and mean values for female thyroid weights are also probably somewhat larger than their true values for a purely statistical reason. The females were killed at many stages of the reproductive cycle; and, as in the human, some of these stages are probably consistently accompanied by a quite temporary enlargement of the thyroid. Through a statistical error these abnormally high temporary weights, certainly obtained from some females, are registered as the more usual and permanent thyroid weights."

PHYSIOLOGY OF SEXUAL REPRODUCTION AND DEVELOPMENT

MICE

Under MacDowell's direction there has been completed the analysis of the breeding records of the mouse colony for the past 4 years. Some interesting statistics have been derived therefrom in respect to litter size.

Litter size, although clearly affected by differences in the care given by different caretakers, shows no clear correlation with season of the year. As in the case of sex ratio, the most certain factor controlling litter size is found to be genetic. One strain stands out consistently with large litters,

another strain with small ones, while the remainder of the strains are intermediate and not differentiated in this respect.

Studies have also been made on the proportion of still births and the sex ratio given by these animals found dead at birth, and on the frequency and distribution of abnormal parturitions. The various correlations have been studied by graphs and scatter diagrams; many probable errors have been calculated in testing the statistical significance of differences between specific groups of data. The data cover five major strains and twelve minor strains; individual records for 67,000 mice are included.

ENDOCRINE STUDIES IN PIGEONS

INSTRUMENTAL AND PHYSIOLOGICAL TECHNIQUE FOR BASAL METABOLISM

Jointly with Dr. Benedict, Director of the Nutrition Laboratory, Riddle has published on the new instrumental and physiological technique developed in their study of the basal metabolism of pigeons and doves. The technical requirements are rather severe since they must permit the detection of such small differences as may exist between the sexes, between different strains or races and between various hybrids and their parent races. The apparatus devised, chiefly by Benedict, and used in these studies include a closed-circuit respiration apparatus for a single dove and another for a pigeon; an open-circuit apparatus for a single pigeon; an open-circuit multiple cage respiration chamber for 10 common pigeons, and a modification of this for use with 10 doves.

The activity recording device is, in general, indispensable. Several independent measures are made and the kymograph records are then used to eliminate values not obtained with the bird in approximate repose.

A special large glass cage permits the birds to remain at a constant temperature during 24 hours preceding their measurement. This cage permits of adjustment of temperature and activity of the birds during this period, since fighting males are under restraint.

The extensive experiences with the basal metabolism of birds has thus led to the discovery of physiological factors that appear to be capable of modifying basal heat production and to their elimination as far as practicable. These precautions are essential to success in measuring such differences as may exist in the basal metabolism of the sexes of different races and of different hybrids among these birds.

The Benedict and Riddle report covers a statement, by Riddle: "concerning the special nature and history of the wide variety of races (24 of doves; 13 of common pigeons) and hybrids upon which these and current studies are based. The dove and the pigeon are, by their accepted classification, more different than are the rat and the mouse; and the distinctness of at least some of the many races of each of these species makes it necessary to treat and tabulate data with full recognition that they are derived from different races or strains. More than a thousand individuals of known pedigree, maintained under excellent conditions, have been continuously available for this study. Autopsies made usually soon after our metabolism measurements enable us to eliminate from consideration all values obtained on diseased birds."

Other findings are as follows: a period of 24 hours must elapse after the last feeding and before beginning metabolism experiments if a fasting quotient (about 0.72) is to be secured. The fasting period should begin toward dusk after feeding. Thus the metabolism measurements begin at the most favorable time, with the onset of darkness. If birds fail to eat at the prescribed time the fast will be too long and values below the standard will be obtained. Hence birds must be hand fed if necessary. Also regurgitation of food and subsequent ingestion nearer the period of measurement must be guarded against, otherwise an increase in both the respiratory quotient and the metabolism results. Temperature is an important factor in determining the rate of heat production in doves and pigeons; since at between 20° and 30° C. each degree of increase raised this rate approximately 2.0 per cent. The respiratory chamber is kept dark to reduce movements of the birds. Measurements must be made exclusively at night—the normal period of repose for these animals. But the hours from 1 to 5 a.m. are best avoided since especially low body temperatures and lowest blood pressures are found to occur then. A repetition of tests, with accompanying fasts is not desirable within a period of 1 week; otherwise the second measurement is often too low. Also prolonged inactivity, say for 4 weeks, remarkably decreases metabolism. Immature, but full-grown birds, have a metabolic rate higher than that of mature birds.

SEASONAL CHANGES IN PITUITARY GLAND

Last year it was reported that Riddle had found that the anterior lobes of the pituitary body contain a substance capable of accelerating the growth of the testes in young pigeons. During the present year he has obtained some evidence that this gland does not become more active during the period of active reproduction—spring and summer. The criterion applied is the length of the intestine, which is believed to increase with the activity of the pituitary. The actual findings as to intestinal length are given in Table 3. The slight differences found are probably not statistically significant. Accordingly it is probable that the enlargement of the liver and spleen, which are regularly enlarged during the reproductive season, is due to something other than pituitary influence.

TABLE 3—*Intestinal length (in centimeters) in healthy ring doves during various seasons of the year*

Sex	Winter	Spring	Summer	Autumn	Number of individuals
Males. . .	52.6	51.3	51.7	52.9	319
Females. .	54.9	53.6	54.3	55.3	281
Mean. . .	53.7	52.5	53.0	54.1	600

GLYCOGEN STORAGE

As is well known, the liver plays an important part in sugar metabolism by storing glycogen. Riddle, in collaboration with Professor E. L. Scott, of Columbia University, has already found that the livers of both doves and pigeons contain unusually small quantities of glycogen; but a full

report on this topic may be delayed until next year. The low storage of glycogen largely explains, says Riddle, the results that in fasting doves and pigeons there occurs an abrupt fall, instead of the expected gradual fall, in the respiratory quotient. It is now clear that this abnormal behavior of the quotient is associated with the low carbohydrate reserves in these birds.

THYMUS AND BURSA FABRICII IN RELATION TO SEXUAL MATURITY

An investigation is being conducted by Riddle, in collaboration with Dr. Křiženecký and Miss Irene Polhemus, upon the relation of thymus and bursa Fabricius to the time of attainment of sexual maturity. This study involves the removal of both thymus and bursa at an early age, with a biopsy or reoperation 3 to 4 weeks later (to make sure that all traces of these organs have been removed). The age at which these operated birds become sexually mature is being compared with the age at which their sibs become mature. It is still too early to make an adequate report on the results.

GENETICS OF SPECIAL TRAITS

MICE

LEUKEMIA

The work on leukemia in mice, carried on by MacDowell in cooperation with Dr. M. N. Richter of the Department of Pathology of the College of Physicians and Surgeons, Columbia University, has made notable progress. This cooperative project has been supported by a special research assistantship from Columbia University and by a special grant from the Carnegie Corporation, secured through the initiative of Dr. J. W. Jobling. Under this grant Elsa B. Corbitt is working in this Department, making blood counts and other observations on mice of the leukemic strain. MacDowell reports on this subject as follows:

"Spontaneous cases of leukemia—Beginning with the eighteenth inbred generation, the mice in the strain now called leukemic have been held for systematic observation into old age. It is probable that leukemia was in the strain before that time, for typical symptoms (enlarged spleen) were casually noted at autopsy and during each of the four generations since that time all branches of the strain have produced leukemic mice with great consistency.

"The picture of leukemia is definite, despite considerable variation in the organs affected. The enlarged spleen is one of the most constant features, usually recognizable early by palpation. All of the lymph nodes may be moderately, or individual nodes excessively, enlarged. The usually enlarged liver supplies the best tissue for the histological diagnosis that is made of every mouse.

"The name, leukemia, refers to the high counts of white-blood cells that characterize the disease; but, contrary to the hope expressed in last year's report, these counts do not afford an early diagnosis. Indeed, the disease may run its course to death without any rise in blood count. Again, weeks after other diagnostic signs appear the white-cell count may rise very suddenly or death may be preceded by a sudden drop from high to normal count. Death may be delayed for months after the disease is manifest, or it may come after the first signs are recognized. Hot weather markedly

hastens the end. The age of incidence is between 7 and 16 months. Since the age of detection is so variable and since there are many chances for death at every age from causes unrelated to leukemia, the rate of incidence has no significance. But the occurrence of leukemia in this strain in comparison with all other strains in the colony is so consistent as to indicate some genetic basis for it. Twenty-three generations of brother-sister inbreeding in this strain is an earnest of great genetic uniformity among all its individuals. The two considerations lead to the conclusion that all the mice in this strain are liable to die of leukemia, but that certain variable secondary conditions influence the onset of the symptoms."

"Genetics of spontaneous leukemia—While the high incidence of leukemia exclusively in one strain among a number raised under similar conditions is evidence of genetic differences, it does not demonstrate that the chromosomes are solely responsible for its recurrence in successive generations. The possibility remains that the chromosomes determine a susceptibility to some external specific substance which is passed from mother to child. The possibility is being tested by the use of foster mothers, by reciprocal matings and by back crosses."

"Experimental transmission of leukemia—In contrast to the findings of all other investigators employing the mouse, this leukemia has been found transmissible from one animal to another by inoculation. Young animals from the leukemic strain are inoculated with macerated spontaneous spleen; they develop the lesions of leukemia and die several months younger than any known spontaneous case. The relatively few failures from such inoculation are ascribed to faulty technique; since reinoculations bring positive results. Spleens from mice with experimentally induced leukemia serve perfectly for inoculating other young mice so that the condition can be handed down from mouse to mouse. All cases starting from the same spontaneous spleen constitute a line of leukemia, and four such lines are being carried at present. The different lines show characteristic reactions, notably in the interval between inoculation and appearance of symptoms and death. Line A has become markedly more rapid than the other lines; at present it has been transferred through 16 young mice. Whatever the material that is responsible for the leukemia, it is certain that it is increased inside the injected animal and has a continuity and individuality which are maintained during passage through a series of individual mice."

"Nature of the material that is active in leukemia—Richter has found the material responsible for the leukemia induced in young animals in affected lymph nodes, heart's blood and ascitic fluid, as well as in the spleen, since inoculations from these sources will induce the disease. Sub-cutaneous and intra-peritoneal injections are equally effective. In line A, where response to the inoculation is prompt, the lesions are strongly localized and intense. In more slowly developing cases the symptoms are less localized and not different from those of the spontaneous cases. So far, macerated leukemic spleens ground with sand, or treated with glycerine for 3 days, or desiccated or incubated for one hour at 56° C. have all given negative results. The same material kept on ice for 7 days gave positive results. The use of filtered inoculants has given negative results. These results are preliminary, but none conflict with the hypothesis that living cells are necessary to induce the disease in young animals by inoculation."

"Genetics of experimental leukemia—The experimental induction of leukemia has been successful only in animals from the leukemic strain. In several other strains small numbers, in one strain (chosen for cross-matings) 100 mice, have been tested. Consequently susceptibility to inocu-

lations as well as spontaneous occurrence has a genetic basis. A second situation is opened for genetic analysis. Of first generation hybrids between leukemic and non-susceptible strains, some have succumbed to the disease; but the rate of incidence is not yet known.

"It is concluded that leukemia is a neoplastic disease, genetically very parallel to carcinoma and other neoplasms. The migratory nature of the white-blood cells introduces complications in the study of leukemia not met in the cases of tumors that may be transplanted to certain positions and continuously observed there. But it may be that these very differences will lead the way to advances in the whole subject of tumor inheritance."

INTERACTION OF COLOR AND SPOTTING GENES IN MICE

Hair pigment is a conspicuous external, post natal character whose development can be easily followed. The restriction of pigment to certain areas in spotted animals is known to be partly under the control of genes. The discovery of this restrictive process might be a step taken toward unraveling the complicated chain of interactions that are started by the genes and terminate in the adult characters. Certain patterns of spotting are directly determined by specific genes. We have next to consider how much of the variability in spotting may be due to genes that have been regarded as primarily effective in other traits. During the year MacDowell has been working in cooperation with Professor L. C. Dunn of Columbia University, who has long been identified with the problem of spotting in mice. Their topic has been: Do the color genes influence the color pattern? The chief result obtained is that the gene for yellow pigment increases the size of the pigmented areas. This is true both when the dominant lethal gene for highly restricted pigment (black-eyed white) is present and when it is absent.

EYE DEFECTS IN MICE

MacDowell has made further progress in the selective breeding of his strain of abnormal-eyed mice, reported upon last year. One branch of this strain has in 2 generations (in which respectively 105 and 155 young have been studied) given 94 per cent of abnormal eyes and 63 per cent with both eyes affected. Three other branches showed no further advance. Through crossing it is hoped to determine the genetic nature of the advance in the progressive branch.

PIGEONS—RACE DIFFERENCES IN THYROID SIZE

Dr. Riddle has just published on this topic and drawn the following conclusions:

"Within a large colony of ring doves, mongrelized to a degree fairly comparable with that attained, or attainable, in mankind, physiological factors influencing thyroid weight have been controlled to an extent which has made possible a demonstration of genetic factors for thyroid size.

"Twenty-four strains, or races, have been studied, and at least four races with characteristically large thyroids and four races with characteristically small thyroids have been definitely established. This is the first demonstrated instance of the conscious establishment of a race on the basis of size or function of an endocrine gland.

"The surviving individuals of these races probably represent the nearest approach yet made to a biological standardization of an organism on the basis of thyroid size and function. This material is, therefore, especially suitable for the solution of a wide variety of biological problems. Ultimately it should particularly assist an interpretation of the relation of grades of thyroid function to certain physical traits in man.

"The attainment of this result was probably assisted by the choice of birds showing various type of reproductive disorder as the parental stock with which to initiate some of these races. A further selection for large or for small thyroid was practised among progenies of the F_1 and F_2 generations.

"Crosses were made between races of all types—large, intermediate and small. Considering merely the average thyroid weight within each generation the results are as follows: Large thyroid \times large thyroid has given large thyroid in F_1 , F_2 and F_3 . Small \times small gives small thyroids in F_1 , F_2 and (partly) F_3 . Intermediate \times intermediate tends (not always) to give intermediate in F_1 , F_2 and F_3 . Apparently, large \times small yields thyroids of intermediate size in F_1 , F_2 and F_3 .

"Questions of dominance, and of the number of genetic factors involved in thyroid size, must await the further accumulation of data from certain crosses. There is no suggestion of sex-linked inheritance of thyroid size in this material. The study is based on the thyroid weights of 1,931 healthy adult offspring of 50 parental ring doves whose thyroid size was also known."

GENES AND THE CONDITIONS OF LIFE UNDER WHICH THEY ACT

Riddle has formulated certain general considerations that grow out of his work. He insists that there is no development which is not the joint action of genes and of specific conditions (using the latter term to designate the intimate physical and chemical environment). Resemblances and differences are not due merely to genes but sometimes to the specific conditions of life. Steps in evolution are made when the advent of a new gene coincides with the advent of a new specific condition, especially when both are capable of perpetuation in development and reproduction.

THE THOROUGHBRED HORSE

This research, in which Laughlin has made substantial progress during the past year, is crystallizing around two subjects which are considered separately below.

THE MEASURE OF RACING CAPACITY

The elements of the problem are sex, age, distance, speed and weight carried on the back. To express racing capacity the highest records for each sex in each combination of distance, weight and age were tabulated. These linear standards were then smoothed; then cross-sectioned into surfaces and again smoothed; and finally the several surfaces were smoothed into relatively precise interrelationships. Mathematically the several major elements were inter-compensated by a system which Laughlin has called the "method of added functions." This system supplied the standards for determining quality of performance. These standards are expressed in the following formulas in which St. M. S. F. means "Standard Mean Seconds per

Furlong"; "a" age in years; "d" distance in furlongs; and "w" weight carried in pounds.

I. For colts:

$$\text{St. M. S. F.} = \text{antilog} \left[\left(\frac{(a-4.25)^2}{200.2821} + 0.070331 \right) \log d + \left(\frac{(w-113)^2}{77107.0687} + \frac{(a-4.25)^2}{-315.6272} + 1.01799 \right) \right]$$

II. For fillies:

$$\text{St. M. S. F.} = \text{antilog} \left[\left(\frac{(a-4.00)^2}{7641.7546} + 0.092667 \right) \log d + \left(\frac{(w-108)^2}{77107.0687} + \frac{(a-4.00)^2}{1586.0428} + 1.000943 \right) \right]$$

III. For geldings:

$$\text{St. M. S. F.} = \text{antilog} \left[\left(\frac{(a-4.50)^2}{744.5678} + 0.082613 \right) \log d + \left(\frac{(w-112)^2}{77107.0687} + \frac{(a-4.50)^2}{-1759.6185} + 1.008309 \right) \right]$$

The quality of performance (Q. P.) is, as stated in last year's report, the ratio of St. M. F. S. divided by actual mean seconds per furlong; and the Biological Handicap, which is the measure of racing capacity of the individual, is a straight line function of it. Approximately 10,000 of these Biological Handicaps have been computed mathematically from actual racing records. This work have taken 5 years. But the correct measures of racing capacity in the individual is a necessary preliminary to investigating the inheritance of this quality.

THE INHERITANCE OF RACING CAPACITY

The first step in this study is the computation of this capacity for a considerable number of near-kin groups. This has been done for numerous branches of the more important thoroughbred strains. Racing capacity is so complex that Mendelian analysis is out of the question. The actual proceeding adopted was to compute Constitutional Indices based on near-kin performance.

The most accurate constitutional index yet employed as a pre-indicator of capacity in the offspring is obtained by comparing the curve of the near-kin indices of 70 mares arranged in ascending order with that of mean racing capacity of the offspring of the particular mares. In this pre-indicating index the four grandparents are weighted 1.0, the two parents 1.0; the half sibs by the common sire 0.5; the half sib by the common dam 0.5; and the mare herself 1.0. Similarly sires and their near-kin are rated, and the near-kin of both sire and dam are combined.

At present Laughlin is engaged in devising new near-kin indices based on different groups of selected near-kin with varied weights applied to each individual. Thus will be found the most accurate basis for predicting the mean racing capacity of the offspring of a sire, a dam or a given mating.

HUMAN GENETICS

HEREDITY FACTOR IN ATHLETIC SUCCESS

The report by Post and the Director on this topic undertaken at the expense of the Carnegie Foundation for the Advancement of Teaching has

been completed and the manuscript submitted to the Foundation. The inheritance factor in success in athletics is as clear as that of racing ability in horses, but like the latter is too complex to admit of Mendelian analysis. Several things come out of this analysis.

First, success in athletics rests upon both favorable constitution and good training, most intimately intermingled and interdependent. Going through the motions of training is not real training. Training results when the motions are made by a trainable person; and with the same motions the training is the more effective the more trainable the individual—*i.e.* the better qualified he is through hereditary constitution.

On the other hand, constitution alone, no matter how good, does not make an athlete. But a fine constitution reacts the more completely and effectively the better the motions through which it is put. Also, the constitution reacts the better to training the more that training is adjusted to the particular constitution to be trained. A slender, light boned person may by training become a fair wrestler; a broad-shouldered, heavily boned person will probably by the same training, other things being equal, become a better wrestler.

"Now the presence of the physical hereditary factor in the athlete is shown not only by the observed facts of the difference in bodily proportions of persons who have been successful in the different types of athletics—a difference that was in part laid down at an early stage of development, probably even before birth—but also in the fact that in certain families of brothers the standard training has led to the same extraordinary result. If two members of the Wikoff family qualified for the 10,000 meter race on the Olympic team it was not merely family tradition, or the exceptional skill of their trainers, but also their suitable body form, their fondness for outdoor activity and for competition, such as their brothers and their only sister also showed and such as their father revealed, and their father's father, who could jump $5\frac{1}{2}$ feet.

"Indeed the correlation in grade of success in brothers who trained for the same sport is in some sports extraordinarily high. In the 440-yard dash we find in our series a correlation of over 0.90. This close correlation gives some indication of the similarity of brothers—of their gifts, on the one hand, and of their limitations, on the other—which determines degrees of success in dashes."

HEREDITY OF GOITER

This research approaches completion. It has been necessary to make repeated visits to Western Maryland to clear up certain points in the pedigrees. Retabulation of some of the data will be required, on account of changes, but it is believed that the main conclusions, provisionally stated in the Year Book for 1926-27, will not be disturbed.

HEREDITY OF SEX-LINKED CHARACTERS

Under a fund contributed by the Research committee of the American Medical Association, Mr. Charles Green made a study of some families with hæmophilia. In reporting his findings, the occasion was taken to review the literature on the main sex-linked characters in man. The manuscript is nearly ready for the printer.

HEREDITY OF OTOSCLEROSIS

The field work of this investigation has been conducted at the expense of the Committee on Otosclerosis, American Otological Society, by Dr. Bess Milles. The cases have been obtained from doctors, clinics and from members of the Volta Bureau who have donated their family histories. The total number of calls made by Dr. Milles was 287, resulting in 65 histories of hereditary deafness and 23 negative histories. Thirty family histories of hereditary deafness have been reported by the Volta Bureau members.

A general consideration of the hereditary histories of families of 2, 3 and 4 generations shows 36 per cent of the members in these families to be affected. Only 9 families showed the deafness to have skipped a generation. Eight families were reported to have several deaf persons in one generation but no knowledge of an affected ancestor.

HEREDITY OF MENTAL TRAITS

For years Banker has been assiduously engaged in getting a basis for the study of heredity of mental traits. Using the records of the school at Huntington he has elaborated the Student's Ability Index (SAI) as a satisfactory measure of inherent ability, in a long series of papers which is held in high esteem by leading psychologists. Banker reports:

"Our material appears capable of statistical use and of showing average associations and tendencies; but is it adequate for specific Mendelian analysis?"

"This more desirable end was sought during the past year by compiling family pedigrees of individuals whose school accomplishments could be expressed in terms of the SAI. The Huntington material was in many respects especially favorable for such treatment and it is scarcely to be hoped that such complete pedigrees can be obtained elsewhere. More than 20 family groups of 20 to 70 individuals each were plotted and many more could be obtained if the results warranted further extension of the work. Some individuals were duplicated in different groups and the SAI's of some could not be determined. Each group consisted of a fraternity, the parental fraternities and usually the grand-parental fraternities, sufficient to show the distribution of mental ability through three generations and whether displaying any law of Mendelian behavior. In general distribution, student ability in these family pedigrees showed the same correlation previously mentioned, that is the SAI's of like value tended to concentrate in proportion to nearness in genealogical relationship. It was found impossible to interpret the distributions in terms of any definite form of Mendelian segregation."

It is found that the school material is perhaps by selection rendered too homogeneous. The extreme mutations are not represented—certainly none are imbeciles. Consequently it is poorly adapted to genetic analysis. Also, Banker finds there is no basis for discriminating types. The lower quartiles of grammar school, high school and college do not represent like genetic types. The phenotypes "high" and "low" can not be identified with a genotype. Moreover, the qualities measured by the SAI are incapable of interpretation in terms of simple Mendelian factors; the SAI is probably an aggregate expression of many factors. A simpler subject SAI may be

computed, but the school records for the parental period, while furnishing marks for total scholarship, frequently fail to give marks for subjects; hence in few families can a subject SAI be obtained for parents and children. Also, rarely does the SAI for a specific subject differ from the SAI for total ability. This is partly accounted for on the ground that our data are derived from the central area of a Gaussian distribution. Banker concludes that it is doubtful if the best of scholarship records can furnish data suitable for Mendelian analysis of mental traits; but they do show tendencies and distinct correlations in abilities, whether inherent or acquired. He reports further:

"From the total body of school records compiled with reference to related individuals, 467 SAI's were computed and found to give a general distribution with the following constants:

$$\begin{array}{ll} \text{Mean} = 99.47 \pm 0.46 & \text{Median} = 100.92 \pm 0.58 \\ \text{First quartile} = 89.96 & \text{Third quartile} = 110.02 \\ \text{Skewness} = -0.2405 \pm 0.0322 \end{array}$$

The mean and median approximate closely to 100 but with a small skewness toward the higher end of the scale. The quartiles are well balanced and give appropriate division points for differentiating three types of ability; low=all below 90; medium=90 to 110 inclusive; and high=all above 110. On this basis a table of selected matings was compiled, including all families in which the SAI was available for both parents and one or more children. There were 38 such families having in all 83 children.

"The distribution of the average shows beautifully the usual regression of the children toward the mean. Especially is there clear-cut evidence of a positive correlation between the quality of children and the type of parental matings; the average SAI's of parents and children present two corresponding series ranging from low to high. The distribution of the children per mating according to type reveals the same fundamental truth; 'low' matings yield children of lower average SAI with a distinct preponderance of 'low' type children, 'high' matings yield children of higher average SAI with an even greater preponderance of 'high' type children. While in some cases ratios in the distribution of types appear strikingly definite none of them seems amenable to positive Mendelian interpretation.

"The general average SAI for the children is distinctly higher than that of the parents, again suggesting that there is a rising tendency in the mental level of the population, but this may be a reflection of the better educational facilities of the later generation and, therefore, an environmental phenomenon rather than genetical. The percentage distribution of the types of children in the various matings suggests, from the rather general over-weighting of percentages at the high end of the scale, that high mentality is an expression of a prevailing dominance in its genetic factors. This is barely confirmed also in the fact that children of a $L \times H$ mating yield a slightly higher average SAI than do children of a $M \times M$ mating."

STANDARDS IN ANTHROPOMETRY AND PSYCHOMETRY

Our work on race crossing in Jamaica brought home very vividly the need of a better standard for measurement of the physical and mental qualities of man. For only when a body of such standards is invented, tried out, and generally accepted and applied by anthropologists and psychologists can progress be made in the study of human genetics. In human

genetics, as in genetics in general, race crossing alone will give an insight into genetical factors.

Fortunately an opportunity arose to inaugurate research in this direction through a gift from the Eugenics Research Association of \$4,000 for the current year, with prospect for more in the future. Under this grant and after consideration by the Eugenics Advisory Committee the following arrangements were made. Mr. Richard H. Post, who has been studying with Hooton at Harvard, was assigned the task of visiting the different countries of Europe for the purpose of conferring with anthropologists as to the best physical measurements to take for inter-racial studies, and the technique to be employed in taking them. He was to visit the international conference on this subject, to be held in Paris in July 1929.

To Miss Barbara Schieffelin was assigned the task of visiting psychologists in the United States with the aim of determining what work is current in the invention of methods of mental measurement and of obtaining their advice as to which are best adapted to inter-racial work. Already, by the end of the year under review, she has accumulated many valuable data for a report.

Beginning in June 1929, in association with Mr. John H. Long of Teachers' College, and Miss Anne Anastasi of Barnard College and Miss Alice Leman Webb, the Director has been making comparative studies on different groups with a battery of 15 "mental tests." The groups being studied are: children aged 6 to 14 of the public schools; mental defectives at Brunswick Home, Amityville, Long Island, and Letchworth Village; blind in the Catholic Institution for the Blind, New York City; post encephalitis cases and various types of the insane at Kings Park State Hospital. Thanks are due to the heads of these various institutions for their cordial cooperation.

The battery of tests was selected to meet the following requirements. The tests should be as independent as possible of language on the part of the examiner and other special culture on the part of the subject. These requirements do not interfere with the use of his own language by the subject and one notes that such language is frequently used during the operations. The above definition cuts out educational tests and makes it necessary to employ many performance tests; but does not limit to such tests. The following are the tests that are being tried out: 1, Hollow square; 2, Seguin form board, blindfolded; 3, Ferguson form board series; 4, Knox cube imitation; 5, Goddard adaptation board; 6, kindergarten bead stringing; 7, cardboard and strings of girl's industrial test; 8, chain of clips; 9, Porteus maze series; 10, copying of a square; 11, drawing of a man; 12, color cubes; 13, painted cube; 14, form-color substitution; 15, nonsense words. In addition, sense discrimination tests, like the Seashore test for aural capacity and the Eugenics Record Office visual form discrimination tests, useful where a minimum of language interchange is possible. The other tests are presented to all alike by pantomime.

GENETIC CONSTITUTION OF THE AMERICAN POPULATION

INCIDENCE OF INVENTIVENESS IN DIFFERENT EUROPEAN STOCKS

This project, described in last year's report, is being pushed to completion by Laughlin.

MIGRATION MOVEMENTS

Studies are being made by Laughlin on the relation between population density, rate of population increase and wealth and commerce per capita to the "push and pull" in present-day migration. This project, like the preceding, is being conducted in collaboration with the Committee on Immigration and Naturalization of the House of Representatives.

EUGENICAL STUDIES ON THE POPULATION OF THE SOUTHERN APPALACHIANS

A final report on this subject has been practically completed by Estabrook. He finds that the economic level of many areas is to a great extent the most important factor determining the biological type of population therein. The broad fertile valleys of the richer plateau lands quickly develop an average economic and social level through agriculture. The more rugged and actually mountainous sections develop more slowly, due to the low average production and the difficulty of transportation. The population over the whole Southern Highland region increased rapidly. In areas of high agricultural production, this increase was easily absorbed. But, in the more rugged regions, through failure of economic opportunity the more energetic and ambitious moved away.

Within the last few decades the development of the natural resources by outside interests has resulted in a permanent change in the economic levels of the areas of activity. Much immigration has taken place of persons of higher average ability and intelligence than those of the local stocks. While in the industrialized areas the intelligence quotient of the school children finds its mode at from 90 to 100, that of the areas where the economic, educational and social conditions are below the average of the state have modal IQ's of 70 and 80.

ADMINISTRATIVE RECORD

The combined libraries of the two sections of this Department comprised June 30, 1929, 12,921 bound books besides numerous catalogued pamphlets. In the archives of the Eugenics Record Office were 1,911 books; 8,972 field reports, 31,335 sheets in special trait files and about 11,800 "Records of Family Traits." We have received during the year 1,603 sheets of various other schedules and 2,756 biographical press clippings. Some 27 collaborators sent in collections of "Family Records" from educational and other organizations, receipt of which has been gratefully acknowledged.

The mouse colony is in better condition than ever before. This is partly due to the replacement of the unsanitary wooden shelves and boxes by metal ones; but most of all is it due to the intelligent care given by Mr. Theophil Lanes. Since the accuracy of the work done with the mice depends on the accuracy and reliability of their caretaker, we feel that Mr. Lanes is making a new and an important contribution to our scientific work.

The twenty-fifth anniversary of the organization of departments of research of the Institution was celebrated at Cold Spring Harbor on May 31 to June 2, 1929. The Department's share of the celebration was under the direct charge of Blakeslee. Exhibits were installed at the Station for Experimental Evolution (under the immediate direction of MacDowell) and the Eugenics Record Office. Addresses were given by Dr. Henry S. Pritchett and General John J. Carty of the Board of Trustees, by President John C. Merriam and by Professor E. G. Conklin of Princeton. Over 900 persons visited the exhibit during the 3 days.

GEOPHYSICAL LABORATORY¹

ARTHUR L. DAY, DIRECTOR

THERMODYNAMIC RELATIONS IN MULTI-COMPONENT SYSTEMS²

The science of thermodynamics deals with work and heat. Since all physical and chemical processes, which thereby include all natural phenomena, involve work and heat it is apparent that thermodynamics is fundamental and widely inclusive in its applications.

For example, a problem, the solution of which is vital to the geologist, is to ascertain the conditions which control the formation of igneous rocks and related deposits from the original magmas. An igneous magma, which conventionally we call a system, consists of a complex solution of silicates and volatile constituents. The relations which determine the stability of such a system form a problem of applied thermodynamics which the Geophysical Laboratory has attempted to solve for the geologist. To do this we are required to evaluate explicitly the thermodynamic relations which exist between the variables of such a system, these variables including temperature, pressure and component masses. The components of a system may be considered as being the chemical species, atoms and molecules, which describe the composition of the system. The theory by which such systems can be treated thermodynamically was first worked out by J. Willard Gibbs. The technique of determining experimentally the magnitudes necessary to be measured in order to evaluate explicitly the thermodynamic properties of such mineral systems was worked out in the Geophysical Laboratory.

Gibbs condensed his theoretical treatment of such systems into a skeleton outline which, although complete, left a great deal of work for the student to do in filling out the steps between his equations. Moreover, he did not indicate the quantities that must be experimentally determined in order to formulate a fundamental equation for any one system—a fundamental equation being a single equation from which all the thermodynamic properties of a system may be deduced. Hence many readers found difficulty in understanding and applying his arguments. In fact some theorems which follow from his treatment have had to be independently rediscovered in order to be recognized.

For these reasons, and since a large part of the work at the Geophysical Laboratory consists of experimental thermodynamics, it was thought desirable to evaluate as many as possible of the thermodynamic relations in multicomponent systems and tabulate them in such form that they may be readily available for use both here and elsewhere, and so during the past year work was begun at the Geophysical Laboratory to carry out this project.

Practically it is an impossible task to attempt the formulation of all possible relations between all the variables here involved. Moreover such an attempt, if it could be carried out, would defeat by its sheer bulk the very purpose for which it was intended. The relations tabulated are therefore

¹ Situated in Washington, District of Columbia.

² R. W. Goranson.

expressed in terms of a certain set of variables, chosen, rather than some other set, because their values, for any one system, can be readily obtained from experiment, and they are all that need be determined to formulate a fundamental equation for any particular system whose state is determined by these variables. Moreover, they are basic quantities in the formulation of the theory.

Furthermore, the concepts of physics have undergone tremendous changes since the days of Gibbs. Concepts, and therefore physical hypotheses, which in his day were accepted as a matter of course, must now be scrutinized carefully in the light of new ideas which have come about through the perfecting of experimental technique. For the concepts, and hypotheses, of physics have meaning only in terms of the methods by which they are measured. Hence when our methods of measurement change, as for instance due to an increase in experimental accuracy, our concepts change and we must therefore be prepared to restate theoretical structures that are based on such concepts.

Again mathematicians have, since Gibbs' treatise was written, developed and perfected the tools of mathematics to keep pace with the increased demands of the physicist. For, as Poincaré has stated, "all laws are deduced from experiment but to enumerate them a special language is needful; ordinary language is too poor, it is besides too vague to express relations so delicate, so rich, and so precise. This therefore is one reason why the physicist can not do without mathematics." In evaluating the functional relationships of thermodynamics, independent variables of two orders are present, and for dealing with independent variables of two orders the methods of partial derivatives and line integrals were especially designed. As W. F. Osgood has said, in thermodynamics a thoroughgoing appreciation of what the independent variables are, and the ability to think in terms of line integrals, are indispensable.

It was therefore thought desirable to restate the theory of thermodynamics in terms of present-day physics and mathematics and to develop the theorems necessary for such a treatment.

As a resumé it may be stated that this project was carried out with the following ideas in mind: (1) To present so much as is needful of classical thermodynamics in a logical and mathematically rigorous manner from the undefined concepts and physical assumptions; (2) To evaluate the mathematical functions in terms of directly measurable quantities and to compute the mathematical relationships obtained between the variables for multi-component systems.

With such a treatment we can, without any difficulty, know exactly how firm our theoretical foundation is and determine the effect of new discoveries from all branches of physics on this science. Furthermore, although mathematics can not deduce new truths from old truths, it can take the hypotheses and deduce consequences which result in ideas for obtaining new truths. But the consequences of the hypotheses must be deduced in a rigorous manner, otherwise we can not be sure that, when used as stepping stones for obtaining new truths, they will not give way under us.

Finally, with the mathematical relationships between the variables evaluated in terms of directly measurable quantities and tabulated so as to be

readily available, we have at our finger-tips data as necessary to the physicist and physical chemist who deal with such systems as the slide rule is to the engineer.

SCIENTIFIC EXPEDITIONS

During the year just closed (July 1, 1929) the Geophysical Laboratory has participated in two expeditions of much more than ordinary interest and significance. The first was a volcano field study on the Islands of Java and Bali in the Dutch East Indies, for the purpose of trying out a new method of volcano study. It was inspired by the fact that here a considerable number of active volcanoes are found within a small area and there is rarely a time when some one of them is not in eruption. These plans were doubtless favorably influenced just then by the news that Krakatau, which in 1883 gave us the most violent volcanic eruption in history, was locally reported to be again showing signs of activity.

The second expedition was quite different in character and took advantage of a favorable opportunity to add materially to our measured data concerning isostatic adjustment within the crust of the earth. Substantially all of the measured fact supporting the present-day theory of isostasy has been gathered by measurements of gravity in geologically significant places. Until recent years these measurements could be made only on land. Latterly, however, Dr. F. A. Vening Meinesz, of the Dutch Geodetic Commission, has devised a form of pendulum with which gravity determinations can be made at sea with a precision nearly equal to the best determinations made on land. Vening Meinesz' pendulum requires for its platform a submerged submarine. It is therefore only possible to make such measurements when a submarine can be made available, and submarines are available only with the official cooperation of Governments. This particular expedition was made possible when the Secretary of the Navy consented to place at the disposal of those interested the Submarine U. S. S. S-21, provided Dr. Vening Meinesz could arrange to join the expedition with his apparatus, and representatives of the Hydrographic Office and of the Carnegie Geophysical Laboratory be associated with him. Dr. Vening Meinesz was enabled to make the journey through a provision for his personal expenses appropriated from the Joseph Henry Fund of the National Academy of Sciences. The expedition thus became a cooperative undertaking in the interest of isostatic studies of the great deeps of the Caribbean Sea, supported jointly by the U. S. Navy, the National Academy of Sciences and the Carnegie Institution of Washington. The U. S. S. S-21 spent some 45 days in the Gulf of Mexico and the Caribbean Sea in the months of October and November 1928 in precise measurements of gravity over the great deeps, the Mississippi delta and adjacent areas.

A brief account of the accomplishments of these two expeditions follows:

VOLCANOLOGICAL STUDIES IN JAVA AND BALI IN 1928¹

The spectrograph has enabled the astronomer to obtain such a wealth of information concerning the temperature, distance and composition of the heavenly bodies that it has occurred to various investigators interested in

¹ E. G. Zies.

volcanic phenomena that this powerful tool could also be used in determining the temperature, kinds of gases and chemical elements present in the flames that issue from volcanoes. The avenues of approach to an active volcano for the purpose of discovering something of its internal mechanism and the sources of its energy are few and very hazardous. A crater in eruption is rarely accessible or even approachable. A possible approach through spectroscopic analysis of flames would have the greatest value, for observations could then be made during a period of considerable activity from a reasonably safe distance. Accordingly last year the Geophysical Laboratory, in collaboration with Mount Wilson Observatory, formulated a plan to find out how much information could be obtained in this manner.

Mr. Harold D. Babcock of Mount Wilson Observatory assembled two spectrographs, either one of which could be mounted on a rigid tripod and could then be easily rotated. One instrument was of the constant deviation type and was equipped with an Uviol glass prism; the second was a direct vision spectrograph equipped with a camera whose lens system worked at a speed of $F\ 1.9$. For obvious reasons the investigator must work at a distance of several hundred feet from the source of the flames, hence both instruments were furnished with condensing lenses in order to gather as much light as possible into the slit of the spectrograph; in addition both instruments had telescope finders. The first instrument had a wider spectral range than the second, but the latter was more compact and portable and in addition had a faster working camera, hence it was better adapted for reconnaissance purposes than the constant deviation spectrograph. Both of these instruments were kindly loaned to the Geophysical Laboratory for use in the field when a favorable opportunity should offer.

On the basis of information obtained through Dr. C. E. Stehn, Director of the *Vulkaandienst* in the Netherlands East Indies, the Island of Java, with its many active and readily accessible volcanoes, seemed to be the most promising field for these spectrographic experiments, and Dr. E. G. Zies, who had just completed a comprehensive study of the fumaroles of the Valley of Ten Thousand Smokes, undertook the investigation.

It was, of course, realized that volcano flames, notwithstanding their spectacular character, are not often seen in accessible places and when they do appear they are likely to be somewhat evanescent and fugitive in their behavior. It might even happen that this particular search would discover no flames, notwithstanding the careful preparations, just as the astronomer's eclipse expedition sometimes fails if the sun is screened by clouds at the critical moment. In the event that no flames should be found, Java possesses such a large number of active volcanoes that chemical studies similar to those carried out in the Valley of Ten Thousand Smokes could be profitably made.

It may as well be chronicled here that no favorable opportunity presented itself for making satisfactory spectrographic studies during the time that Dr. Zies remained on the islands of Java and Bali, but the gases, incrustations and lavas which were collected there have provided most interesting material for laboratory study. It is also true and of some importance that the possibilities and limitations of a spectrographic investigation are now much more clearly apprehended as a result of the field effort.

It was early appreciated that the great variety of information obtained with the spectrograph by the astronomer will not necessarily be duplicated when this instrument is used in the study of volcano flames. The difference in temperature in the two cases is so very great that this can not be expected. The spectrum of doubly ionized calcium found in the stars means a temperature of several thousand degrees, while the large amount of water vapor present in volcanic gases will in all probability confine the temperature phenomena in a volcano within a range somewhere between 1000° and 1500° C.

One effort was made to use this carefully prepared equipment on Mount Raoeng in East Java, where blue flames could be seen issuing from a vent on the bottom of the crater. It was in some respects fortunate that the work was attempted at this volcano because the difficulties presented by the terrain must be the first to be considered by anyone attempting spectrographic work in the field. Raoeng volcano is about 3,300 meters high and its crater is about 600 meters deep; the crater walls are so steep that no one has as yet succeeded in reaching the bottom. The observation point on the rim of the crater proved to be about 1,300 meters from the flame orifice in the bottom. At this distance the flames appeared to be about one meter high. They did not, however, issue continuously from a single vent, but tongues of flame were moving to and fro along a fissure in a manner so uncertain that satisfactory observations could not be obtained from them. Then, too, the steam issuing from nearby vents often provided a white background instead of the dark background required to register the flames effectively; furthermore, the turbulent character of the air currents in the huge crater often caused the steam to envelop and conceal the flames completely. Night observations which might be expected to bring some relief from the disturbance imposed by the steam, encounter other difficulties; in Java at elevations of 3,300 meters a high cold wind begins to blow at nightfall, against which a substantial shelter must be provided for both observer and instrument.

The difficulties and limitations thus imposed on the spectroscopist and the ephemeral character of the flames themselves both indicate that the investigator must be prepared to bide his time until a really favorable opportunity presents itself—when activity of the flaming type persists over a period of several days or even weeks at a volcano where a reasonably good observing station has been established. Prospects for such favorable conditions are good in Java because many active volcanoes are available there within a relatively small area, and supplies can be quickly transported from several strategically located observation points.

CHEMICAL STUDIES

There are about thirty active volcanoes on the islands of Java and Bali. This unusually active area is an especially favorable region for making chemical studies of volcanological phenomena. The general geological and petrographical features of the islands have been determined and excellent field work is already being conducted there by the Volcanological Survey (Vulkaandienst) with headquarters at Bandoeng, Java. The Geophysical

Laboratory is greatly indebted to this efficient organization for its cordial cooperation in all of the field work which we attempted there.

In 1928 the activity throughout the islands of Java and Bali was in the solfataric or fumarolic stage. Volcanoes in Western, Middle and East Java were visited and samples of lava, fumarolic incrustations and gases were collected for laboratory study. The percentage of the so-called insoluble gases in the emanations was determined in the field. Contrary to our experience in the Valley of Ten Thousand Smokes it was found that the percentage of these gases was different at each volcano and seemed to bear a definite relation to the temperature of the emanations—the higher the temperature the greater the percentage of insoluble gases. It is quite probable that the ratio of these gases to the steam could be used in determining whether the activity of any given volcanic vent is waxing or waning.

A particularly noteworthy feature is the alteration of the walls of the craters by the gaseous emanations. At Tangkoeban Prahoe in West Java the andesite rock of one of the crater walls has been much altered and alunite and sulfur have been deposited in the vesicles of the rock. At the sulfur volcano, Papandajan, alteration of the wall rock has taken place on a huge scale. At the present time the rock of Kawah Mas (The Golden Crater), probably a lava plug, is being broken down by the sulfur-steam emanations (temperature about 300° C.). Tellurium and arsenic sulfide are also present in the emanations and have been concentrated at the cooler periphery of each vent. Laboratory study will no doubt reveal the presence of other products that have been concentrated by virtue of difference in vapor pressure for a given temperature. This work is now in progress.

The volcano Merapi in Middle Java was emitting steam and hydrochloric acid from the lava plug that has been slowly extruded in the course of the past forty years. The temperature of the emanations was as high as 500° C., and to judge from the amount of alteration of the andesitic rocks of the plug the concentration of acid must be relatively high.

At Kawah Idjen, one of the rim volcanoes of the huge Idjen Caldera in East Java, the emanations contain both sulfur and hydrochloric acid. Here again the acid gases have altered the rock of the crater walls. The crater lake of Kawah Idjen is of considerable interest on account of the relatively high concentration of HCl and H₂SO₄ in the water (3.5 per cent of mixed acids). A detailed analysis of this water will be undertaken and especial stress will be laid on the determination of the presence or absence of unusual elements and constituents.

At Batoer on Bali a basaltic cone is located within a great andesitic caldera. In 1926 a lava flow broke through the wall of one of the craters of Batoer and deposited about 21 million cubic meters of lava in the caldera. During this period the fumarolic activity in the crater itself was insignificant but in the course of two years following the eruption fumarolic activity increased considerably as is shown by the fact that the temperature of the emanations was in the neighborhood of 450° in 1929. Insoluble gases were present to the extent of about 50 per cent. The activity of the fumarole gases in altering the rock of the crater-wall here suggested the idea that such activity may, in an active volcanic area, even play an impor-

tant rôle in weakening the wall structure and thus aiding an imprisoned lava to escape.

Attention was also directed to the steam explosions that occasionally take place on the Island of Java, not in the volcanoes themselves, but in cultivated fields where there was no indication of thermal activity previous to the explosion. Such an explosion took place in the Dieng area early in 1928. The force of the outburst was so great that the ground was shattered for about half a mile from the eruption center. The amount of carbon dioxide and hydrogen sulfide escaping from fissures along one of the native highways was so great and proved to be so dangerous that the authorities were compelled to close the thoroughfare for several weeks. It is quite probable that such a relatively high concentration of carbon dioxide and hydrogen sulfide in the water or water vapor imprisoned underground may be a significant factor in the formation of some ore deposits.

The results of both the field and laboratory studies will be presented in later papers.

GRAVITY-MEASURING CRUISE OF THE SUBMARINE U. S. S. S-21¹

The purpose of gravity measurements is clearly shown if we consider a homogeneous sphere and its gravitative attraction for points on its surface. The law of gravitation as formulated by Newton states that two masses attract each other in proportion to their masses and inversely to the square of the distance between their centers of mass. On a sphere every mass point is at the same distance from the center of the sphere and the gravitative attraction of the sphere is the same for all points on its surface. The earth is a rotating body of known mass and rotational velocity. By measuring the value of gravity over its surface and comparing the observed values with computed values we can ascertain its shape or figure. Newton found by computation from the data then available that the figure of the earth is a rotational ellipsoid whose polar axis is $1/229$ shorter than its equatorial axis; the standard spheroid now used in geodetic work differs only slightly from that of Newton; its polar axis is $1/297$ shorter than the equatorial axis; this is the mathematical surface that most nearly coincides with the earth's actual surface or geoid. The primary purpose of gravity measurements is therefore the accurate determination of the true figure of the earth.

The earth's surface is, however, irregular. Great mountain masses, such as the Himalayas, rise to heights exceeding 29,000 feet above sea-level; great ocean deeps extend to 32,000 feet below sea-level. Gravity measurements have shown, however, that a mountain mass is not actually an extra, uncompensated load on the earth's surface; it is not carried, like a load on a bridge, by a strong, non-yielding structure. If the masses of the columns of rock of equal cross-section extending down to a certain depth, called, depth of compensation, are compared they are found to be equal; in other words mountain masses are elevated because the column of which they represent the top consists of rocks of less density than the rocks underlying depressed land surfaces. This condition of equilibrium, whereby the sur-

¹ F. E. Wright.

ficial portion of the earth called the crust is supported in a balanced condition by the material of the interior is called isostasy. Broadly stated the term isostasy refers to the fact that the shape of the earth as a whole is the expression of the figure of equilibrium attained by a body of the dimensions, properties and rotational velocity of the earth; also that if shifts of load occur as a result of the transfer of material by rivers, or otherwise, corresponding adjustments in the crust and the earth as a whole take place to restore the state of equilibrium and to maintain the isostatic balance.

Gravity measurements over the land areas of the earth prove that the earth's crust is everywhere in a state approaching equilibrium. Wherever large departures do occur, they indicate excess or deficiency of load and these in turn produce stresses in the earth's crust. High mountain masses are not eternal but are soon worn down and effaced. If they are actually extra loads on the earth's crust, they give rise to abnormally high gravity values and to high gravity anomalies. Over the great ocean deeps which are commonly narrow depressed troughs or down-warped, local portions of the earth's crust, we find large negative anomalies that are a measure of the deficiency of mass in the deep and thus of the stresses that are present in the down-warped crust. Gravity anomalies above a certain value serve to locate unstable portions of the earth's crust where movements are taking place so rapidly that compensation has not kept pace with the disturbance and where therefore earthquakes due to shearing stresses are likely to occur. A knowledge of these factors, especially of the order of magnitude of the stresses active in mountain building, earthquakes and other crustal movements, is fundamental to geologic theory and can best be obtained by gravity measurements over areas not yet compensated.

In planning the itinerary of the cruise of the S-21, the effort was made to select areas that promised results of interest, such as the continental shelf, the Sigsbee Deep and the Mississippi Delta of the Gulf of Mexico, the Bartlett Deep of the Caribbean Sea, the Nares Deep north of Porto Rico and the normal value of gravity over the deep portions of the Caribbean Sea and the Atlantic Ocean. Gravity measurements at sea are valuable because thus far only a few such measurements have been made and yet the sea covers 72 per cent of the surface of the globe; many of the earthquakes that affect land areas originate in adjacent submarine areas; measurements at sea are moreover less affected than measurements on land by local attractions that tend to produce local anomalies that are difficult to interpret. On the sea surface over depths of a mile or more, these local anomalies are less pronounced and hence the anomalies observed represent more faithfully the condition of the earth's crust.

The observed values of gravity for the stations occupied by U. S. S. S-21 are listed below; also the computed values for the same stations after isostatic compensation. The differences between the observed values and the computed values are the gravity anomalies. The distribution of these anomalies indicates that the Nares Deep is a recent uncompensated geologic feature in which shearing stresses of large magnitude are present; the Eastern part of the Bartlett Deep is also uncompensated; likewise the small Deep between St. Thomas and St. Croix of the Virgin Islands. The Mis-

Mississippi delta is practically compensated in spite of the fact that each year a load exceeding one twentieth of a cubic mile of sediment (nearly 12 billion tons) is being laid down. On the other hand the large positive anomalies over the deeper portions of the Gulf of Mexico, the Caribbean Sea and the Atlantic Ocean indicate a condition for which a satisfactory explanation has not yet been found. This is one of the problems that awaits satisfactory solution; the same condition exists over the Pacific Ocean in so far as measurements have there been made. Further data of measurement over different portions of these ocean areas will be needed before general conclusions can be drawn.

When it is realized that during the past 35 years approximately 300 gravity stations have been occupied in the United States and that during the cruise of the S-21 nearly 50 stations were occupied within a period of two months, the effectiveness of the new method for measuring gravity is obvious. Inasmuch as the value of gravity measurements increases with the number and spread of gravity stations over the surface of the earth, especially over the ocean surfaces, the contribution of the S-21 cruise to the theory of isostasy and to fundamental geologic theory is of lasting value and should form the starting point for other measurements of similar nature over more extended areas.

During the cruise, 46 gravity stations at sea were occupied; in addition gravity measurements were made in the harbors of the Naval Base at Norfolk, Virginia; of Key West, Florida; of Galveston, Texas; of Guantanamo Bay, Cuba; of San Juan, Porto Rico; and of St. Thomas, Virgin Islands. The time occupied by each measurement was normally 30 minutes, which meant a submergence of 35 to 60 minutes. With smooth seas, the depth of submergence was 42 to 45 feet, the limit of periscope depth; otherwise the depth was from 60 to 90 feet, depending on the state of the water. Even at the maximum depth a roll of 5° to 6° on a side was common; at a point 100 miles southeast of Cape Hatteras a roll of 10° on a side at 80 to 90 feet depth was encountered. The gimbals of the gravity apparatus were so constructed that a roll up to 6.5° on a side was permissible; with greater rolls the apparatus failed to clear the support and this prevented the making of measurements off Cape Hatteras as we had planned.

The gravity apparatus of Vening Meinesz is essentially an accurate time-measuring device and consists primarily of three pendulums mounted in a straight line along a metal bar. These pendulums are free swinging, 25 cm. long, and have a period of 0.5 second. By a system of mirrors attached to the top of each pendulum, the combined effects of the vibrations of pendulums 1 and 2 and of 2 and 3 are obtained; in other words, the pendulums are used in pairs, the central pendulum with its two mirrors, one on each side, serving as the second pendulum of each pair. The movements of each pendulum pair are recorded on a strip of photographic paper. In the actual operation of the apparatus, pendulums 1 and 3 are given small, equal, but opposite amplitudes of vibration, while the central pendulum remains stationary. If a horizontal acceleration is subsequently introduced, all three pendulums are affected equally; the record of each pendulum pair registers only the differences in the angular changes between the two pen-

Tentative gravity values in the Caribbean Sea and the Gulf of Mexico

No. of Sta.	Depth fm.	Latitude (ϕ)		Longitude λ		Observed gravity at Sta. (g) Dynes	Theo- retical gravity (g) Dynes	Correction for topog. and compens. dynes	Isostatic anomaly (g-gc) dynes
1 Hampton Roads.....		°	'	°	'				
2.....	15	32	56.7	78	19.9	979.903	979.903	+0.020	.....
3.....	26	32	03.6	79	58.0	979.492	979.492	+0.018	.....
4.....	37	28	20.5	80	05.5	979.20	979.20	+0.029	.....
5.....	210	24	53.5	80	29.6	978.952	978.952	+0.031	.....
6.....	1867	24	52.0	84	07.0	979.025	978.950	+0.057	+0.018
7.....	1823	24	47.0	84	27.0	978.868	978.945	-0.079	+0.002
8.....	1900	24	45.0	86	05.0	978.959	978.942	-0.042	+0.059
9.....	1925	25	06.7	89	22.0	978.950	978.967	-0.036	+0.019
10.....	1993	24	59.7	90	36.2	978.991	978.960	-0.034	+0.065
11.....	907	25	01.3	93	22.5	978.979	978.961	-0.041	+0.059
12.....	73	26	24.0	93	45.2	979.058	979.058	+0.004	.....
13.....	1021	28	04.5	92	05.5	979.225	979.181	+0.025	+0.019
14.....	535	27	21.7	89	04.8	979.153	979.128	-0.002	+0.027
15.....	530	28	15.0	89	11.0	979.216	979.194	+0.007	+0.015
16.....	1220	28	46.3	88	44.5	979.246	979.234	-0.003	+0.015
17.....	1727	28	20.0	87	55.5	979.149	979.200	-0.034	-0.017
18.....	1815	28	52.0	86	17.5	979.109	979.092	-0.042	+0.059
Key West..		26	08.5	85	29.0	979.011	979.040	-0.054	+0.025
Galveston..						978.973	978.973	+0.035	.....
19.....	1332					979.275	979.275	+0.007	.....
20.....	1470	21	33.5	76	16.0	978.628	978.735	-0.063	-0.044
21.....	1582	21	08.3	74	59.3	978.629	978.709	-0.044	-0.036
22.....	2867	19	12.5	75	52.5	978.554	978.596	-0.028	-0.014
23 Moro Castle....		19	30.5	75	53.0	978.417	978.614	-0.136	-0.061
24.....	2530	19	57.4	75	52.5	978.748	978.639	+0.087	+0.02
25.....	3770	19	18.0	76	45.5	978.515	978.602	-0.109	+0.022
26.....	942	19	36.5	76	51.0	978.425	978.620	-0.208	+0.013
27 Guanta- namo....		19	53.3	76	51.0	978.681	978.635	-0.010	+0.056
28.....	5	19	54.5	75	08.9	978.	978.636	+0.085	.....
29.....	2205	20	27.0	72	26.7	978.450	978.668	-0.096	-0.122
30.....	2257	20	24.0	71	21.5	978.456	978.665	-0.095	-0.114
31.....	2520	19	32.5	68	35.0	978.379	978.616	-0.069	-0.168
32.....	4300	19	38.0	67	45.8	978.336	978.621	-0.176	-0.109
33.....	2540	20	13.0	67	46.0	978.668	978.655	-0.012	+0.025
34.....	2800	22	09.5	67	35.0	978.784	978.772	-0.004	+0.016
35.....	3045	21	48.5	66	30.3	978.738	978.750	-0.017	+0.005
36.....	2920	20	35.0	66	25.5	978.701	978.676	-0.010	+0.035
37 San Juan	4210	19	46.5	66	14.0	978.297	978.629	-0.139	-0.193
38	5	18	27.8	66	06.8	978.690	978.556	+0.148	-0.014
St. Thomas.	5	18	20.0	64	56.0	978.690	978.549	+0.141	± 0.000
39.....	2367	17	55.5	65	06.0	978.400	978.527	-0.066	-0.061
40.....	970	17	37.5	65	13.3	978.559	978.512	+0.058	-0.011
41.....	2517	15	47.0	67	43.0	978.440	978.421	-0.029	+0.048
42.....	1652	16	18.0	71	48.7	978.474	978.444	+0.006	+0.024
43.....	2296	16	50.0	73	04.8	978.471	978.471	-0.052	+0.052
44.....	1737	18	45.8	76	26.0	978.545	978.572	-0.051	+0.024
45.....	1100	19	57	74	31.	978.	978.639	-0.010	.....
46.....	952	22	56.5	74	6.8	978.	978.822	+0.029	.....
47.....	2512	23	31.8	73	59.5	978.	978.861	-0.056	.....
48.....	2512	26	16.5	74	00.0	979.	979.050	-0.010	.....
49.....	1562	32	27.0	74	12.0	979.	979.524	-0.031	.....

dulums and is thus automatically freed from the effects of horizontal accelerations; in other words each pendulum pair behaves as a simple pendulum unaffected by the small horizontal disturbances that may occur. This elimination of the horizontal accelerations is the new improvement introduced by Vening Meinesz and makes possible the use of a pendulum apparatus on board a moving but fairly steady platform, such as a submerged submarine or a ship on a calm sea.

In addition to the records made by the two pairs of pendulums, the photographic paper receives and registers: (a) the time signals from two chronometers, the one sending sidereal time, and the second, mean time; (b) the movements of two damped pendulums, the one swinging in a plane parallel with the plane of the pendulum pairs and recording the roll of the ship, the second swinging in the plane normal to the first and recording the pitch of the ship; (c) the fluctuations in the temperature of the air space within the apparatus. The vertical accelerations of the platform due to wave-action are also recorded and give rise to a rhythmic fluctuation of the time signal breaks. The temperature of the air space within the apparatus is read off on a precision mercurial thermometer mounted in a dummy pendulum. The humidity is measured by a hair hygrometer mounted inside the apparatus. In addition the barometric pressure and the temperature are measured outside the apparatus. With the 30-minute exposure the gravity value should be accurate to one part in 300,000.

PUBLICATIONS

- (669) Transmission of elastic waves through surface-rocks. Roy W. Goranson. Terr. Magn. Atm. Elec., 143-148. 1928.

Elastic disturbances are propagated through rock in a definite determinable manner. Thus if sufficient data are available to draw up a time-distance curve for such a disturbance there is a straightforward mathematical procedure for obtaining the sub-surface rock structure. Two time-distance curves of earthquake disturbances are presented and the corresponding interpretations of the Earth's crustal structure. An attempt is made to indicate the correspondence between time-distance curves obtained from rock structures on the scale of the Earth's crust and similar rock structures extending to depths of only a hundred or so meters, as for example salt domes.

- (671) Geologic thermometry. N. L. Bowen. (Chapter 10, 172-199, from *The laboratory investigation of ores*. Edited by E. E. Fairbanks. McGraw-Hill, New York City. 1928.)

A discussion of the sources of information regarding the temperatures of formation of rocks and mineral deposits together with a statement of the general conclusions reached.

In some instances the temperature may be measured directly and by this method definite results have been obtained as to the temperatures of lava flows, fumaroles, geysers and hot springs.

In general it is necessary to reach conclusions as to the temperatures of formation of rocks and minerals by deduction from the physical-chemical properties of minerals and mineral mixtures as measured in the laboratory. The measured melting temperatures of minerals and simple mixtures are very useful as constituting indicators of maximum temperatures above which the minerals concerned can not have formed. Inversion temperatures

are the most serviceable of all indicators of the temperatures of formation of minerals. The various mineral forms of silica are particularly important on account of the widespread occurrence of these minerals. Quartz is known to form only below 870°C . (at atmospheric pressure) and in addition occurs in two modifications with an inversion at 573°C . Certain characters of the quartz in a given occurrence may render it possible to determine whether it crystallized above or below the 573° point.

With the aid of measurements and indications such as these, it has been concluded that most igneous rocks crystallize at temperatures below 870° and, in general, at decreasing temperatures with increasing silica content. Most mineral deposits and ore-bodies are formed at temperatures below 573° . Important deposition occurs at decidedly lower temperatures, some of it but little above the ordinary temperature.

(672) Olivine: I. From the Hawaiian Islands; II. Pure forsterite. M. Aurousseau and H. E. Merwin. *Am. Mineralogist* 13, 559-564. 1928.

Analyses and optical descriptions of two olivines from Hawaii are given, and the presence of Fe_2O_3 and Na_2O is discussed in relation to effects upon optical properties. Dispersions of the refractive indices of pure forsterite, an olivine from Fayal, and one from Hawaii were determined and the effects of Fe_2O_3 considered.

(673) Scientific papers at the 1928 meeting of the Section of Volcanology, American Geophysical Union. *J. Wash. Acad. Sci.* 18, 509-515. 1928.

Abstracts of five papers, of which four were given by members of the Laboratory. These are:

(1) Present volcanic activity over the Earth. H. S. Washington. Pages 509-510.

This report includes the years 1926 and 1927, during which volcanic activity was moderate, and there are no especially noteworthy eruptions to be recorded.

(2) The year's volcanological publications. Arthur L. Day. Pages 510-511.

An account of the books, periodicals, reports and other publications in the field of volcanology appearing in the year 1927.

(3) The classification of the hot areas in the Yellowstone Park and the causes of their development. E. T. Allen. Page 511.

A discussion of the characteristics which distinguish the various hot areas in Yellowstone Park.

(4) The acid gases contributed to the sea during volcanic activity. E. G. Zies. Pages 511-512.

Attention is directed to the importance of the hydrochloric and hydrofluoric acid given off during the various stages of volcanic activity. It is shown that an appreciable amount of the chlorine of the sea and of the fluorine of the great sedimentary phosphate beds may have been derived from such gases.

(674) The lattice dimensions of spinel (MgAl_2O_4). E. Posnjak. *Am. J. Sci.* 16, 528-530. 1928.

Diffraction data were obtained from artificial spinel by the "powder method." The length of the edge of the unit cube containing eight molecules of MgAl_2O_4 is 8.03 ± 0.01 . The calculated density of spinel is 3.628.

- (675) *Radium in rocks: I. The radium content of some representative granites of the eastern seaboard of the United States.* Charles Snowden Piggot. *Am. J. Sci.* 17, 12-34. 1929.

This is the first paper of a projected series dealing with an investigation of the radium content of the rocks composing the lithosphere. It describes in detail an apparatus and technique which, after many changes, have proved satisfactory for this work, and gives the results of an examination of seven representative granites of the eastern seaboard of the United States from Georgia to Maine.

The investigation was undertaken to determine, if possible, what inter-relationships might be revealed by a correlation of the radium content of the rocks of the Earth's structure with all other available geologic and petrographic information, and to secure data bearing upon certain controversial questions concerning the influence of radioactivity on geologic phenomena.

- (676) *Freezing-point—Solubility data for non-metallic systems containing more than three components.* F. C. Kracek. *International Critical Tables*, vol. 4, 424-429. 1928.

An extract from Volume 4 of the *International Critical Tables*.

- (677) *The mass-spectrum of lead from bröggerite.* C. N. Fenner and C. S. Piggot. *Nature* 123, 793-794. 1929.

A sample of lead (in the form of the tetramethyl compound), extracted from the mineral bröggerite, had been sent to Dr. Aston in Cambridge, England, for study by means of his mass spectrograph, and the results had been published by Dr. Aston. Three isotopes of lead, of atomic weights 206, 207 and 208, had been found, and the second of these was regarded as having been derived from an isotope of uranium.

The present article discusses the results further in the light of our analysis of the mineral, especially from the point of view of age calculations. It is found that the numerical values of the lead isotopes, as determined by the mass spectrograph, are hardly in sufficient agreement with those indicated by analysis to serve as a check in calculations of age.

- (678) *The crystal structure of covellite.* H. S. Roberts and C. J. Ksanda. *Am. J. Sci.* 17, 489-503. 1929.

The structure of covellite was worked out by X-ray spectrographic methods. The unit cell was found to be hexagonal with the dimensions $a_0 = 3.802 \text{ \AA}$, $c_0 = 16.43 \text{ \AA}$ and $c_0/a_0 = 4.321$. It contains six copper atoms and six sulphur atoms in Wyckoff's special positions (d) and (f), and (a) and (e) respectively of space group D_{6h}^4 , where $u_{Cu} = 0.093$ and $u_S = 0.126$. All of the other combinations of special cases in D_{6h}^4 that seemed to offer any hope of satisfying the data were tested by comparing calculated with observed intensities, and none was found to be satisfactory. The assigned structure offers a satisfactory explanation for the perfect basal cleavage and for the possibility of gliding parallel to the base.

- (679) *The system, cupric oxide-sulphur trioxide-water.* E. Posnjak and G. Tunell. *Am. J. Sci.* 18, 1-34. 1929.

The system, cupric oxide-sulphur trioxide-water, has been studied over the temperature range, 50° – 200° C .

The following eight crystalline phases were encountered: CuO (tenorite); $4\text{CuO} \cdot \text{SO}_3 \cdot 3\text{H}_2\text{O}$ (brochantite); $3\text{CuO} \cdot \text{SO}_3 \cdot 2\text{H}_2\text{O}$ (antlerite); $3\text{CuO} \cdot 2\text{SO}_3 \cdot 5\text{H}_2\text{O}$; $\text{CuO} \cdot \text{SO}_3 \cdot 5\text{H}_2\text{O}$ (chalcantite); $\text{CuO} \cdot \text{SO}_3 \cdot 3\text{H}_2\text{O}$; $\text{CuO} \cdot \text{SO}_3 \cdot \text{H}_2\text{O}$; and

$\text{CuO} \cdot \text{SO}_3$ (hydrocyanite). None of the solid solutions which had been previously reported as occurring in this system was found to exist.

The conditions under which these substances are formed, the ranges of their stabilities, and their relations to one another were ascertained, and some light thus thrown upon the genesis of the two basic cupric sulphates, antlerite and brochantite, which form a large part of the ore in the enormous deposit at Chuquicamata, Chile. The geometrical and optical crystallographic properties, and the X-ray diffraction patterns of some of these compounds were determined. The confusion regarding the crystallography of tenorite was cleared away: Story-Maskelyne's conclusion was shown to be correct and the conflicting statements of others were proved erroneous. The data obtained are presented in tables and graphically by means of diagrams.

(680) The preparation of projection diagrams. F. E. Wright. *Am. Mineral* 14, 251-258. 1929.

In crystallographical, optical, and X-ray work with crystals, projection diagrams of several different types are widely used, especially for the graphical analysis of data of measurement. In crystallography, the gnomonic and stereographic plots serve the purpose best; in crystal optics, the stereographic, orthographic and angle projections; in X-ray analysis, the reflection and gnomonic projections. These projection plots represent the sphere with its parallels of latitude and longitude, spaced either 1° or 2° apart. The equations that form the basis for these projection plots are easily derived; the mode of derivation affords a clear insight into the relations between the several projections. It is shown that the reflection projection bears the same relation to the gnomonic projection that the gnomonic bears to the stereographic; also that a new projection which represents the entire sphere within a circle of unit radius bears the same relation to the stereographic that the stereographic does to the gnomonic projection.

(681) The rock suites of the Pacific and the Atlantic basins. Henry S. Washington. *Proc. Nat. Acad. Sci.* 15, 604-609. 1929.

Petrographic provinces of igneous rocks are exemplified on the largest scale by the Continental masses and the ocean-floors; the former are granitic and the latter are basaltic, on the whole. The igneous rocks of the Pacific basin differ markedly from those of the Atlantic basin. These differences have been ascribed by many petrologists to the differences in the type of crustal movements that are associated with each of the two basins, and all igneous rocks are referred by many to only two "suites." A protest is here made against this two-fold division. The origin of the continents and the ocean-basins is a difficult problem in geophysics, and one that has been neglected. It is suggested that it was a consequence of areal heterogeneity in the original liquid Earth. The persistence in location of the sun-spots and of the red spot of Jupiter is cited as evidence of the possibility of such persistence of areal heterogeneity in a fluid globe.

(682) The crystallization of basalts. Clarence N. Fenner. *Am. J. Sci.* 18, 225-253. 1929.

A discussion of certain problems connected with the differentiation of igneous magmas. It has been maintained by some geologists, and accepted by many others, that the primary magma of igneous rocks is basalt, and that all other magmas have been derived from basaltic magma as residual liquids left by more or less complete crystallization. Difficulties in accepting this process as the sole agency are pointed out. Theoretical reasoning indicates that by the crystallization of ferromagnesian minerals the residual

liquid should be enriched in iron; whereas to pass from basalt to andesite or rhyolite, a diminution of iron is necessary. Numerous examples are given in the paper to show that the expectation of enrichment in iron through crystallization is in agreement with what we actually find, and that the last liquid residues in basalts contain large amounts of iron minerals and are very different in composition from andesites and rhyolites.

The conclusion is reached that the course of differentiation actually followed in magmas is probably not that which crystallization alone would effect; therefore, that other processes cooperate with crystallization to bring about the differentiation of magmas.

(683) The system: leucite-diopside. N. L. Bowen and J. F. Schairer. *Am. J. Sci.* 18, 301-312. 1929.

The system, leucite-diopside, is of the simple eutectic type. Leucite (KAlSi_2O_6) melts at $1686 \pm 5^\circ$ and diopside ($\text{CaMgSi}_2\text{O}_6$) melts at 1391.5° . The eutectic is at 61.5 per cent diopside and the temperature is $1300 \pm 2^\circ$. Both the liquidus of leucite and that of diopside have the unusual form of reversed curves.

Mixtures of leucite and diopside may be regarded as the simplest possible leucitites. Natural leucitites are much more complex and will be completely liquid at considerably lower temperatures. They will, moreover, in virtue of a notable content of Na_2O , partake somewhat of the complex reaction relations exhibited in diopside-nephelite mixtures.

The inversion of leucite and consequent straining of the crystals may be a material aid to the thorough transformation of leucite to that intergrowth of orthoclase and nephelite known as pseudo-leucite.

(684) The fusion relations of acmite. N. L. Bowen and J. F. Schairer. *Am. J. Sci.* 18, 365-374. 1929.

Acmite is found to melt incongruently with separation of hematite, and its melting or crystallization, with perfect equilibrium, can be expressed in terms of the join $\text{Na}_2\text{O} \cdot 4\text{SiO}_2 - \text{Fe}_2\text{O}_3$. The results of investigation of this join are given in the present paper. This investigation shows that the incongruent melting of acmite occurs at 990° , hematite separating and the liquid having the composition $\text{Na}_2\text{O} \cdot 4\text{SiO}_2$ 71.5, Fe_2O_3 28.5, acmite itself having 34.5 per cent Fe_2O_3 . The temperature must then be raised to about 1275° (nearly 300°) before complete solution of hematite occurs. Crystallization of a liquid of the composition of acmite is, with perfect equilibrium, the reverse of the above. Hematite reacts with liquid at 990° to produce acmite.

If the reaction is incomplete some liquid remains in excess. Upon lowering of temperature acmite separates from this liquid, and at 850° it is joined by quartz, which forms sharp bipyramids analogous to the phenocrysts of many rhyolites. With further cooling the crystallization passes into the ternary system and is complete only at the ternary eutectic acmite-quartz-sodium disilicate. It is suggested that the excess sodium silicate in many rocks bearing acmite and related sodic amphiboles is the result of crystal fractionation of the above type, controlled by the incongruent melting of acmite.

(685) The polymorphism of sodium sulfate: I. Thermal analysis. F. C. Kracek. *J. Phys. Chem.* 33, 1281-1303. 1929.

Although Mügge (1884) and Wyruboff (1890) observed that thenardite, the low temperature form of Na_2SO_4 , is permanently altered by heating to 200° , thermal studies heretofore have yielded only one thermal arrest on

cooling curves, at 234°. Differential heating and cooling curves starting with thenardite that had never been heated beyond 125° showed that a number of thermal arrests are yielded between 195° and 250°. These fall naturally in two groups. The lower group, comprising four heat effects, occurs only on first heating. The upper group is partially reversible, and consists of two heat effects. Optical examination confirms the results of thermal analysis. The facts are interpreted on the basis that the salt is pentamorphic. The behavior of the salt depends largely upon the presence of minute inclusions of solvent (H_2O) or small amounts of H_2SO_4 , which increase the speed of the inversions and notably reduce the hysteresis which accompanies them. As a consequence of the accelerating effect of the inclusions of small amounts of H_2SO_4 , one of the heat effects occurring in the lower group of inversions is made reversible. The irreversibility of the lower group is nevertheless such that even in this case the salt does not revert to thenardite on cooling.

(686) The polymorphism of sodium sulfate: II. The densities of anhydrous sodium sulfate at 25°. F. C. Kracek and R. E. Gibson. *J. Phys. Chem.* 33, 1304-1308. 1929.

At least two modifications of anhydrous sodium sulfate can exist indefinitely at ordinary temperature and pressure. These forms, thenardite or $\text{Na}_2\text{SO}_4\text{V}$, and $\text{Na}_2\text{SO}_4\text{III}$ have at $25.00 \pm 0.01^\circ \text{C}$. densities of 2.664 ± 0.001 and 2.697 ± 0.001 respectively.

(687) Annual Report for this year.

(688) The system potassium metasilicate-silica. F. C. Kracek, N. L. Bowen, and G. W. Morey. *J. Phys. Chem.* 33, 1857-1879. 1929.

The system $\text{K}_2\text{SiO}_3\text{-SiO}_2$ contains three compounds, $\text{K}_2\text{O.SiO}_2$, $\text{K}_2\text{O}.2\text{SiO}_2$, and $\text{K}_2\text{O}.4\text{SiO}_2$ whose melting points are 976°, 1036° and 765° respectively. The respective eutectics between these compounds are at 775° and 45.5 weight per cent SiO_2 , and 752° and 69.0 weight per cent SiO_2 . The eutectic between $\text{K}_2\text{O}.4\text{SiO}_2$ and high quartz is at 764° and 72.0 weight per cent SiO_2 , very near the $\text{K}_2\text{O}.4\text{SiO}_2$ composition. $\text{K}_2\text{O}.2\text{SiO}_2$ presents an unusual type of liquidus curve, and enters into solid solution with excess of both K_2O and SiO_2 , the solid solutions decomposing into the pure compound and a melt at 814° and 993°, on the two sides of the composition of the compound. A reversible inversion is found in $\text{K}_2\text{O}.2\text{SiO}_2$ at 590°.

(689) The mystery of ancient glassware. George W. Morey. *Art and Archaeology*, vol. 28. Dec. 1929.

A sketch of the development of glass compositions from the earliest known and dated glassware to the present time. It is particularly emphasized that although the manufacture of glass has progressed from the crudest handicraft to a highly mechanized industry, the composition of glass has changed but little, and that in minor aspects, throughout the ages. The reason for this is to be found in the chemical relationships among the few possible glass-forming ingredients, which place such definite limits on the proportions in which a glass can be compounded as to make its composition almost unique.

(701) Thermodynamic relations in multi-component systems. Roy W. Goranson. In press.

In this volume are developed and listed the thermodynamic relations in homogeneous multi-component systems and it is shown what quantities are necessary to be measured in order to evaluate these relations for any one system.

Under the headings: fundamental ideas, simple homogeneous systems, binary systems, and n-component systems, are developed the functional relations between the thermodynamic quantities from the undefined concepts and physical hypotheses for the "equilibrium processes." In this treatment it is assumed that the work received can be expressed by the integral $-\int p dv$. This is not always true, one important exception being solid systems strained by force fields. Under the headings: strain, stress, stressed-strained systems, and stress-strain relations for isothermal changes of state, are developed the thermodynamic relations for stressed solid bodies, and this extension of the work definition is sufficiently general to be readily applicable to systems acted on by other force fields.

Irreversible processes are then discussed since any physical meaning assigned to the hypotheses stated earlier in the volume must come from a consideration of such processes.

The second part of this volume includes an introduction to the tables of thermodynamic formulas (first and second derivatives) and the tables themselves. The introduction to the tables discusses the notations and abbreviations used and the experimental determination of the standard derivatives in terms of which all the formulas are expressed.

The notation and abbreviations have been so chosen that 18,480 first derivatives and 2,016 second derivatives are listed in such a form that they are readily accessible and consume a minimum of space. Moreover these derivatives are so expressed that any derivative not listed can be obtained from these tables plus either formal differentiation or algebraic elimination.

DEPARTMENT OF HISTORICAL RESEARCH¹

The present account of the activities of the Department of Historical Research constitutes its twenty-sixth annual report, the Department having been established in 1903, the first of the organized research divisions of the Carnegie Institution of Washington.

On June 30, 1928, Dr. J. Franklin Jameson retired from the directorship of the Department, after twenty-three years of service, to occupy the newly created chair of American history in the Library of Congress. It would be impossible to overestimate the influence which Dr. Jameson's incumbency of the directorship of the Department has exerted upon the advancement of historical studies in the United States. It is enough to say that the innumerable services he rendered in that position to all historical interests were as distinguished and fruitful as they were unselfish. The members of the Department's staff rejoice that Dr. Jameson's position in the Library of Congress makes possible the continuance of those personal and scholarly relations that have been so valued and inspiring.

Dr. Jameson's retirement has been followed by certain transitional modifications in the Department's organization and operations. Its general affairs have been administered by the staff, informally organized as a steering committee, while all office matters have been despatched and the editorial work of the Department performed by its secretary, Miss Cornelia M. Pierce.

Since 1903, the director of the Department had also served as managing editor of the *American Historical Review*, and members of the staff had assisted in editing that journal. The retirement of Dr. Jameson terminated this activity of the Department, except that until the end of December Miss Marguerite M. McKee, a member of the staff, continued to serve as secretary of the *Review*, while Mrs. Louise F. Pierce, the stenographer of the Department, continued to assist Dr. Dana C. Munro, who succeeded Dr. Jameson as managing editor of the *Review*. At the close of 1929, both Miss McKee and Mrs. Pierce resigned from the Department, to accept positions with the *Review* and the American Historical Association, respectively.

The Institution has, however, been able to continue for another year its cooperation with the American Historical Association, to the extent of placing office accommodations at the disposal of both the Association and the *Review*. It is believed that this arrangement has been helpful to the Association, while it has been agreeable and advantageous to the staff of the Department.

Detailed reports respecting progress on the major projects of research are presented below. It will be noted that while the first four of these are in the charge of the permanent members of the staff, Doctors Leland, Burnett, Stock and Paullin, the last two are carried on by scholars temporarily associated with the Department, Mrs. Helen T. Catterall and Professor Elizabeth P. Donnan. In addition to these temporary associates the Department

¹ Report submitted by W. G. Leland. Address, No. 909 Tower Building, Washington, D. C.

has had the advantage of five months of Mr. David W. Parker's services in Paris, assisted for part of that time by Miss Janet Woodburn.

In addition to the projects on which detailed reports are presented, other undertakings of the Department have been advanced during the year. The work on the *Guide to Materials for American History in Dutch Archives* has benefited from Dr. Jameson's kind attention to the revision of certain parts of the manuscript during his visit to The Hague in 1928. Dr. Tor Berg, of the Riksarkivet in Stockholm, has completed that part of the work on the *Guide to Materials for American History in Scandinavian Archives* that was left unfinished by the death of Dr. Erik Naumann. Professor Charles W. Hackett has been able to make some progress with the third volume of *Historical Documents relating to New Mexico, Nueva Vizcaya, etc.*, while volume IV of the *Correspondence of Andrew Jackson* (1829-1832), volume II of *European Treaties*, and volume II of *Judicial Cases concerning American Slavery and the Negro* have all been published within the period covered by this report.

Of miscellaneous activities and matters more or less personal to the members of the staff, the following may be noted: Dr. Jameson represented the Carnegie Institution in the Sixth International Congress of Historical Sciences, of which he was one of the honorary presidents, held in Oslo in August 1928. Dr. Leland delivered a public lecture at the Carnegie Institution in November, on "French Sources of American History," and later spoke on the same subject at the Library of Congress. He also attended in August 1928 the International Congress of Historical Sciences at Oslo, and in May the meetings in Venice of the International Committee of Historical Sciences, of which he is treasurer, and in Brussels the meetings of the International Union of Academies, of which he is vice-president. Dr. Burnett has lectured at the Library of Congress on "The Papers of the Continental Congress." Dr. Stock has been elected president of the Catholic Historical Association and one of the editors of the *Catholic Historical Review*, and has lectured at Mt. St. Mary's College and at the American University on "The Settlement of the Roman Question." He has also served as chairman of the Committee on Publications of the American Historical Association, and has served on the editorial board of the *Historical Outlook*. Dr. Paullin has assisted the *Dictionary of American Biography*, as a contributor and also in an advisory capacity, with respect to biographies of American naval officers. Doctors Burnett, Leland and Stock attended the meetings of the American Historical Association in Indianapolis at the close of 1928.

Special mention should not fail to be made of the valuable cooperation of the Library of Congress through providing facilities and accommodations for the work of Doctors Stock and Paullin and of Professor Donnan, as well as in many other ways.

Guide to Materials for American History in the Archives and Libraries of Paris, by Waldo G. Leland

The volume devoted to manuscripts in Parisian libraries has progressed to page proof, but the necessity of revising the index, which was made out-

side the Department, has prevented the prompt publication of the volume. During the summers of 1928 and 1929 Dr. Leland was able, in short visits to Paris, to continue his examination of the consular archives of the Ministry of Foreign Affairs, while Mr. David W. Parker, aided by Miss Janet Woodburn, completed the examination of materials in the colonial and marine archives and in the Archives Nationales. The manuscript for the volumes dealing with the colonial and marine archives, prepared by Mr. Parker, is now ready for final revision before going to press.

Letters of Members of the Continental Congress, by Edmund C. Burnett

The selection and annotation of the materials for volume V of the *Letters of Members of the Continental Congress* have been completed to the end of the year 1780 with the exception of some scattered unfinished notes, and much of this has been prepared for the press. In addition, certain sorts of annotation, considerable in the aggregate, have been carried through the years 1781 and 1782. It is not now, however, expected that the volume will extend beyond the middle of the latter year, inasmuch as extensive additions to the materials for 1780 have been made since the estimate of two years ago.

The most considerable addition from a single source has been the letters of a committee sent to headquarters in the spring of 1780 to cooperate with General Washington and serve as an intermediary between him and Congress, on the one hand, and between the army and the States, on the other. Chiefly because of the large bulk of the committee's correspondence, it was originally planned to omit these letters, but so much of the proceedings of Congress during the five months of the committee's activity hinged upon the proceedings of the committee that it has been deemed necessary for the sake of clarity to include the principal of these letters.

The despatch of this committee to headquarters was symptomatic of the serious situation in which Congress found itself in the early months of 1780. In the latter part of 1779 the utter collapse of the money system had led Congress to adopt the plan of requisitioning specific supplies from the States; but that plan also brought little but bitter disappointment, partly because of the fundamental defect of requisitions, partly because of the continued depreciation of the money and the consequent rise of prices. In March 1780 Congress adopted a measure which it was hoped would check depreciation and stabilize prices. Its actual effect seemed to be the acceleration of both processes. The committee of cooperation, though its creation was almost a gesture of despair, did much toward redeeming a critical situation in the army, but, when its task was only well begun, it was suddenly recalled. A majority in Congress began, characteristically, to fear that the committee was becoming too much infected by "camp doctrine"; that is, was showing too great a tendency to take the army point of view.

On the military side, the year 1780 stands for the loss of Charleston (Savannah had fallen the year before), and the ignominious defeat of Gates; but it also stands for the signal victory at King's Mountain. The year 1781 stands, of course, for the redemption of the South by General

Greene and a group of partizan officers, the surrender of Cornwallis at Yorktown, and the virtual end of the war.

In the sphere of legislation, the year 1780 is marked by the renewal of efforts in Congress to reform its management of executive business; and these efforts resulted in the creation, in the early months of 1781, of executive departments controlled but not conducted by Congress. In this sphere the most significant feature of the year 1781 was the final adoption of the Articles of Confederation. Those Articles, the framing of which had been completed in November 1777, had been sent to the several States for ratification, had been returned to Congress with many proposed amendments and there threshed over again, but by the early days of 1779 had been accepted by twelve of the thirteen States. Maryland alone had held off because some of the States persisted in claiming for themselves the great western territory which, in Maryland's view, had been won by the sacrifices of all, and it was not until the beginning of 1781 that such a solution of the problem was attained as would induce Maryland to accept the instrument of union that was proposed. Accordingly, on the first day of March 1781, the delegates of Maryland, authorized by an act of assembly, appended their signatures to the Articles of Confederation. The union of States was at last on a constitutional basis. And yet it is a fact worth noting, that few actual changes took place in the conduct of Congress or in the record of its proceedings. This further fact, although probably only to a minor extent consequential, is noteworthy, that the years 1781 and 1782 are marked by the beginnings of a series of constructive legislative acts on the part of Congress—acts of permanent moment in our history.

Proceedings and Debates of the British Parliaments respecting North America, by Leo F. Stock

During the past year the manuscript of the third volume of the *Proceedings and Debates of the British Parliaments respecting North America* (1542–1783) was completed, and some progress made with the assembling and editing of texts for volume IV.

The volume now awaiting publication, covering the years 1703–1727, begins with the first Parliament of Queen Anne and ends with the death of George I. If during this period there is not yet evident a policy of parliamentary control over the colonies, there is no lessening in variety and interest of matters that here pass in review to richly illustrate almost every phase of colonial life. In the petitions, reports, hearings and legislation therein recorded will be found information concerning mail service, postal rates, coinage, manufactures, the preservation of timber, naval supplies, activities of trading companies, the transportation of Palatines and felons, the sending of ministers by the Society for the Propagation of the Gospel, charter difficulties, and treaty negotiations at Utrecht.

With the act of union in 1707 there is an end of the Scottish Parliament, which otherwise was engaged in its closing sessions in settling the business of the Darien Company. American references in the proceedings of the Irish Parliaments are restricted to legislative provisions for the transportation of felons and enactments of duties on colonial products.

The heretofore unpublished materials drawn upon for the text and annotation of this volume include documents from the Additional Manuscripts in the British Museum; the Manuscripts of the House of Lords; and, for the section devoted to Scotland, Supplementary Parliamentary Papers, being incidental documents used by the clerk register in framing the official records.

Through the kindness of Dr. Jameson, of the Library of Congress, a quantity of material was received from the British Museum for the years 1738-1779, and from the Manuscripts of the House of Lords for the period of present study. Miss Ruth A. Fisher, of London, supervised the photostating and copying of these. For succeeding volumes, transcripts of the Manuscripts of the House of Lords will be available through the Manuscript Division of the Library of Congress.

European Treaties bearing on the History of the United States and its Dependencies, by Charles O. Paullin

In April the second volume of Miss Davenport's *European Treaties bearing on the History of the United States and its Dependencies*, covering the years 1650-1697, was published. The third volume, covering the years 1698-1715, the materials for which, with the exception of a few treaties for 1713-1715, were assembled and edited by Miss Davenport, is for the most part ready for final revision preparatory to printing. The literature relating to treaties for the years 1716-1815 has been thoroughly searched by the present editor and the relevant treaties and parts of treaties for this century have been discovered and selected. The photostating of texts in London, Paris, and other foreign capitals has been well advanced toward completion. This work was greatly facilitated by Dr. J. F. Jameson during his visit to Europe in the summer of 1928. A considerable part of the photostats received here have been typed at the Library of Congress, where Miss Florence P. Spofford, an expert in deciphering old manuscripts in the foreign languages, has been of great service. The copies completed by her have been collated and annotated by the editor. Dr. Herbert F. Wright, of Georgetown University, has made translations of the Latin, and Dr. James A. Robertson, of the Florida Historical Society, of the Spanish texts. The series will end with the fourth volume and the year 1815.

*Judicial Cases concerning American Slavery and the Negro, by
Helen T. Catterall*

After reading the proof of volume II of *Judicial Cases concerning American Slavery and the Negro*, work was commenced on the material relating to the Gulf States, and the excerpts from the Georgia and Florida Reports have been made and the introductions for those States written. The Alabama excerpts have been brought down to 1846.

The cases from this southernmost tier of States show an unwillingness to favor freedom not often found in the States farther north. The emancipation acts of Georgia are interpreted so as to make wills and deeds void which transpose "remove and set free" to "set free and remove," and finally, in 1859, the "post mortem manumission" of slaves is forbidden.

The growing opposition to the American Colonization Society, favored at its inception by "the wisest and best men of the South from Maryland to Louisiana," is brought out by Judge Lumpkin, in 1857, in an opinion which questions whether the society should even be allowed to sue in the courts of Georgia.

The constitution under which Florida was admitted to the Union forbade the legislature to pass any emancipation law, so that that fruitful subject of litigation is almost absent from the Florida cases. Free negroes and privileged slaves appear to have been abhorred there as elsewhere, theoretically, at least; but practically, as elsewhere, there are facts which belie the theory. A striking instance is that of a partnership between a slave and a white man in the "blacksmithing business" in 1863.

The Supreme Court of Alabama, in 1838, held that the constitution of 1819, giving the general assembly "power to pass laws to permit the owners of slaves to emancipate them," "impliedly abrogated all pre-existing modes of emancipation," including that by will.

The justices of the Supreme Court of Alabama did not become excited, in 1837, over the case of M'Donald, a free negro, who had tried to instigate a slave to start an insurrection. They held that his "conviction was unauthorized," as the instigating suggestions had failed to instigate and there was no actual insurrection on foot.

The counsel of slaves charged with capital offenses exhaust every legal resource to obtain their acquittal, and the Supreme Court of each State usually reverses the judgment of the lower court against the slave whenever there is a legal loophole for the prisoner's escape from his sentence. This lenity does not seem to be only for the sake of preserving the owner's property, but because of justice and humanity.

The problem of the runaway slave hardly exists in these States, at least not in the law reports. He often runs away to his former master's home, but does not usually attempt a permanent escape.

Among other facts bearing on the history of slavery, these excerpts give the terms of the hire and sale of slaves, the States from which they are brought and those to which they are removed, the large number of negroes owned by one person, the proportion between the size of the plantation and the number of working slaves employed thereon. They show the unwillingness of masters to part with family slaves, the diseases of slaves and the medical attendance furnished them; the condemnation, by the community as well as by the courts, of those masters and overseers who inflict cruel punishments.

These excerpts are as disconnected as are the adjacent columns of the daily paper; but as the newspaper reader follows the sequence from day to day of those subjects which claim his interest, so may the reader of these pages. And he can feel more assured that what he reads is true, since the evidence is given under oath; that the opinions and comments of the judges are probably more impartial and dispassionate than the editorials of that day, as the judges would usually be chosen for their intelligence and fair-mindedness. He will see vividly before him the daily life of the plantation, "the unimaginable accidents, the little notes of truth for which the common lense of history" is "not sufficiently fine." He will listen to the very con-

versations between slave and overseer in the moment of punishment, to the accounts of eyewitnesses of crimes committed by slaves and those of which they are themselves the victims, to the talk of slave with slave.

Documentary Study of the Slave Trade, by Elizabeth Donnan

In the plan for documenting the history of the negro in this country, outlined by Dr. J. F. Jameson, former director of the Department, there was included as one of its component parts provision for a series of volumes on the slave trade. The end of the summer of 1929 has seen completed the material for three volumes illustrative of the history of this trade to the Western world from its beginnings through 1807, the date which marked its end as a legal traffic. It, however, continued its existence long after that year but as an outlawed trade.

Any attempt to present the slave trade to the thirteen colonies of the North American continent, either by document or narrative, as a thing apart from the history of the traffic as a whole would be both useless and misleading. That trade was but a part of a world traffic and can be examined intelligently only in its world setting. Throughout the seventeenth and eighteenth centuries the commerce in negroes was the "big business" of Portugal, Holland, France and England; for its conduct the machinery of the corporate trading company was developed; it was the lever by which Spanish-American markets were opened to the rest of the world; friction arising from it helped to bring on most of the wars of these two centuries; desire for its welfare guided England's colonial policy, as well as her policy toward her European neighbors. It was the foundation on which much of the industry of England rested, and the means by which the resources of the new world were exploited. It accomplished the largest human migration the world has ever seen, and it has left a set of social problems as yet unsolved.

To deal adequately with all these aspects of the traffic within the limits of three volumes is manifestly impossible, but the attempt has been made to illustrate most of them, and to develop some in considerable detail, the emphasis being always on the business methods and the economic importance of the trade rather than on its political effects or its influence on the diplomacy of its time. Since the negroes of North America were chiefly transported by the English, by far the larger body of documents relates to the English trade, the Dutch, French and Spanish activities being given a minor place. To the English there was no distinction between the traffic to the West India colonies and the colonies of the continent; the same methods of supply were developed; the same orders issued. A cargo unsold in Jamaica might be carried to South Carolina or Georgia, or a captain who sold his first cargo in Barbados might carry his second to the Carolinas. The chief difference is to be found in the fact that since the West India need for slaves was the earlier one, the Royal African Company played a larger part in supplying it than did the separate trader; while the markets of the continental colonies, of greater importance in the eighteenth than in the seventeenth century, were more largely exploited by the separate trader, either English or American, than by the company. In addition to supplying her own colonies, England through the last quarter of the seventeenth

century and all of the eighteenth had a large share in furnishing the blacks needed in the Spanish settlements of the Caribbean region, and no account of her slave trade can omit this branch if the development of the trade is to be understood.

Volume I, 1441-1700, deals with the exploitation of the African coast by the Portuguese, French, Dutch and English, the opening of the West India markets, the development of the trading monopolies and their struggles with the interloping trader.

The outstanding topics in volume II are the long struggle between the advocates of an open trade and those who upheld the monopoly form, the attempt of the South Sea Company to maintain a profitable trade to Spanish America, the reorganization of the company in 1750, and the resistance of the commercial interests to the efforts of the abolitionists. The growth of the abolition movement itself is not developed, since the supply of literature on the subject is already of tremendous volume and easily accessible. Throughout both these volumes much material is presented with intent to show the nature of the business itself, as carried on by the companies and by the separate traders, in England, in Africa, and in the colonies.

In volume III is segregated the material strictly limited to the continental colonies. Read in the light of the information in the earlier volumes, the American trade becomes, as it should, a part of the larger traffic. Obviously, to present the history of the trade of all the colonies *in extenso* is impossible. Yet to print a few illustrative documents for each colony has not seemed a particularly useful service. Economic sources do not lend themselves to concise treatment. Diplomatic history can often be illuminated by a single protocol. The history of a long series of negotiations may be summed up in one significant document. In economic history, on the other hand, an event is significant because of its recurrence. The small thing which happens over and over again becomes of importance by reason of its repetition. To present this recurrence by means of original material demands large space.

As a compromise, a few colonies have been treated in detail; the others in briefer fashion. Massachusetts and Rhode Island, as the chief trading colonies, Virginia as the most important of the border markets, and South Carolina as the great market of the South, have been chosen for as complete presentation as possible. For other colonies, the accounts illustrate some feature of the trade peculiar to the colony, or neglected elsewhere.

The materials have been gathered from many sources: first and most plentiful are the official papers of government agencies. The Public Record Office, and the archives of Spain, Holland and France offer a bewildering abundance, only a small portion of which could be here used. The papers of the English African companies, the South Sea Company, the Merchant Venturers of Bristol, the Dutch West India Company, as well as those of private merchants in England and America, have all been drawn upon. Newspapers, narratives written by captains, surgeons and travelers, statutes, court cases, controversial pamphlets have all contributed to the collection. The store is unlimited and the volumes do little beyond sampling the supply of sources available for the study of this subject.

DEPARTMENT OF MERIDIAN ASTROMETRY¹

BENJAMIN BOSS, DIRECTOR

The past year has brought the Albany Catalogue of star positions practically to completion, enabling a greater concentration upon the problems of the General Catalogue.

THE ALBANY CATALOGUE

Since the last report, the reductions of the Albany observations to the equinox of 1910 have been completed. For the stars between $+80^\circ$ and $+90^\circ$ of declination the third term was derived from trigonometric expansions and applied to the 1910 places. This quantity was appreciable for only a few stars.

The scrutiny of the individual results has been completed, leading to the correction of some manifest errors of computation and the rejection of certain sporadic observations where no source of error was found or could be assumed. During the checking a careful watch was kept for individual series of observations which might still contain systematic differences not eliminated by the application of personal corrections. While three series were found to require revision, there were several others containing stretches of a large fraction of an hour in which all the stars seemed to have been bodily shifted either north or south to the amount of a second or more. The possibility of abnormal refraction is eliminated, since the shift at zenith and equator are alike instead of being dependent upon zenith distance.

Notes to individual stars have been prepared for publication in the final catalogue. These largely apply to double stars of which both components were not observed and to discordant results either included or rejected. The manuscript for the printer has been prepared as far as eleven hours of right ascension and half of it has been checked from the duplicate cards. As a check against possible duplication of the same error on the two computation sheets the manuscript positions and coefficients are being compared with the general card catalogue. In this manner there have been found a few gross errors which were overlooked in the careful search for the ordinary minute ones. The Albany Catalogue will contain the positions of 20,811 stars.

THE GENERAL CATALOGUE

As steps in the reduction of the Albany observations have been cleared up, more of the staff have been employed in the computations upon the General Catalogue. The first step to be undertaken is the derivation of the systematic corrections to and weights of those catalogues which will be used in forming the positions and motions of the stars in the General Catalogue. In addition to the catalogues used in the formation of the Preliminary General Catalogue and the fifty whose systematic corrections and weights were determined some nine years ago, there are over eighty in process of treatment which will be employed in determining the positions

¹ Address: Dudley Observatory, Albany, New York.

and motions of the stars of the General Catalogue, with the promise of a few more to be added soon. Many of the new catalogues, some of them kindly supplied by the authors in manuscript, have been transcribed on to the cards of the card catalogue which contains for each star to be incorporated in the General Catalogue the listed positions taken from the catalogues of observations. Thus the positional history of each star is available.

As one of the preliminary steps in the derivation of positions and motions, the observed positions as listed on the cards are compared with provisional ephemerides. Considerable work has been accomplished in extending the ephemerides and comparing them with the observed positions.

Three courses are open for the further development of the General Catalogue. First, the system of the Preliminary General Catalogue might be adopted as offering a homogeneous system which could be corrected at any time in the future. There is, however, now available sufficient evidence of the imperfection of that system to argue against its reproduction. Secondly, a new standard system might be formed by a complete revision from the ground up. That would require the expenditure of more time and energy than the circumstances would appear to warrant. Consequently the course we are adopting consists in the reduction of the observations to the system of the Preliminary General Catalogue and the revision of that system upon the evidence furnished by the fundamental catalogues. This procedure will save duplication of the work already done in forming the Preliminary General Catalogue and, while not as rigorous as a complete revision, will provide a system but slightly inferior. In view of the fact that any standard system constructed today will require revision after the lapse of another twenty-five years, the course adopted seems justified, especially since the primary object of the General Catalogue is to furnish star positions and motions which will serve our present-day requirements.

Some tentative steps have been taken toward correcting the system of the Preliminary General Catalogue. New material has been used for a comparison of declinations observed from opposite sides of the equator for the revision of the adopted refractions. The indications are that the corrections to the declinations depending upon declination and to the proper motions in declination will not differ widely from those found three years ago, though there will naturally be greater precision in detail.

The revision of the system of right ascensions of the Preliminary General Catalogue will require an investigation of the magnitude equation. As one of the preliminary steps the magnitude equation resulting from a combination of the Albany and San Luis observations was determined. In both sets of observations the same precautions were taken to free the observations from magnitude effect by the employment of screens, in addition to the determination of the magnitude equation of the individual observers. The indicated correction to the Preliminary General Catalogue depending upon magnitude was found to be:

$$\Delta\alpha_M = -0.0011 + 0.0015(m - 4.0) + 0.0005(m - 4.0)^2$$

We take pleasure in acknowledging the generous aid of colleagues who have furnished us with results of observations for incorporation in the Gen-

eral Catalogue. At our suggestion the re-reduction of the Leiden 1865.0 catalogue was undertaken. Catalogues in manuscript were sent to us by Dr. Gonnessiat (Algiers 1925) and by Dr. Zimmer (Cordoba 1916), and Dr. Martin's Dunsink Zodiacal Catalogue was obtained through Dr. Comrie and Professor Eichelberger.

MISCELLANEOUS INVESTIGATIONS

DIURNAL AND SEASONAL VARIATIONS

An attempt is being made to determine the physical action underlying the diurnal changes in clock rate and the seasonal variation in right ascensions, but the investigation has not progressed far enough to warrant discussion at the present time. It may be mentioned, however, that such strong correlations as are evidenced between diurnal variations in temperature, clock rate and in the level of the instrument are highly suggestive of a common cause behind all three phenomena.

STELLAR MOTIONS

A study by Wilson of the space velocities of over 4,200 stars shows that 99 per cent may be represented by a series of six Maxwellian functions of the form $F(V) = \sum A_i h_i^2 V^2 e^{-\frac{1}{2} V^2 / h_i^2}$. F_1 contains 61 per cent of the stars, the motions being random about a mode of 18 km./sec. F_2 , with 19 per cent, is composed largely of stars of the Ursa Major and Taurus streams, distributed around a mode of 34 km./sec. F_3 , with 10 per cent, represents stream motion among the late-type giants, particularly those of K type, about a mode of 52 km./sec. Among the B and A stars 99 per cent of the velocities are represented by F_1 and F_2 . The first three functions include in the following classes: F, 99 per cent; Gg, 94 per cent; Kg, 91 per cent; and Mg, 97 per cent. The dwarf stars have velocity frequency characteristics quite different from those of the giants, 95 per cent of the K and M dwarfs falling in a single Maxwellian distribution about a mode of 58 km./sec., a value close to their median velocity. The last three functions are due primarily to the superposition of dwarf frequencies upon those of giants and can not be considered as well defined, though they are due largely to asymmetry in the stellar motions. The study of the velocity frequencies leads to a logical system of grouping according to velocity dispersion which isolates some of the velocity characteristics. Velocities less than 25 km./sec. may be assumed to be largely random; from 25 to 45 km. they are largely influenced by the Ursa Major and Taurus streams; and from 45 to 65 km. the major influence is a similar, though less pronounced, streaming among the late-type giants.

With these groupings solutions have been made to determine the solar and preferential motions as indicated by stars of different velocities, types and luminosities. The results show the same trends as have been noted heretofore, but are considered to be more representative because of the use of more inclusive groups. The weighted mean solar and preferential motions are:

A_0 275°5	A_1 94°1	A_2 334°6	A_3 189°5
D_0 +31.8	D_1 +13.4	D_2 +64.1	D_3 +21.7
V_0 18.8 km.	σ_1 28.1 km.	σ_2 20.4 km.	σ_3 14.8 km.

The principal advance consists in a more accurate determination of the motions of the solar apex and the direction of preferential motion around the galaxy with increasing velocity dispersion. This phenomenon shows its reflex in the distribution of the apices of stellar motions, after the mean solar motion has been taken out, in the motions of the two vertices of preferential motion as determined from the concentrations of the stellar apices. The motion of Vertex I is shown to be but 30° , while that of Vertex II is at least 80° . The directions of solar and preferential motion derived from the mathematical analysis are shown to be resultants of the motions of the two vertices. The study shows that stream motion is apparent among stars of all speeds and all types; that this, in itself, produces asymmetry in all stellar motions, so that the motions are not in general distributed according to the ellipsoidal law; that the progression in the coordinates of the solar motion with increasing velocity dispersion is due to this asymmetry; and that the progression in the direction of preferential motion is due primarily to the changes with increasing stellar speed in the position of Vertex II, but another manifestation of the asymmetry.

Stromberg has shown that this asymmetry may be thrown along one axis directed toward galactic longitude 61.5 , latitude $+9.0$. Wilson's results are well satisfied by this longitude but indicate a tilt out of the galactic plane of but 3° , which is too small to satisfy Stromberg's data. He finds that both sets of data may be satisfied with a reasonable degree of accuracy by the mean tilt $+6^\circ$. The relation between displacements along this axis and internal velocity dispersion, as determined from his data, is well satisfied by Stromberg's parabolic formula. With reference to the set of axes defined by this direction ($l = 61.5$, $b = +6^\circ$) and assuming the deviations from this axis in the fundamental plane to be constant, he gets as coordinates of the limiting center, $x' = -10.1$, $y' = -10.0$, $z' = -4.1$, values in exact agreement with Stromberg. Due to the difference in axes, the coordinates of the solar motion in the local cluster are slightly different, Wilson's values being $A = 268^\circ$, $D = +22^\circ$, $V_0 = 14.8$ km.

It is noted, however, in Wilson's results and in those of Stromberg in general that the deviations from the fundamental axis in the fundamental plane are not constant but lie upon a curve, the center of which lies in longitude 306° and the radius of curvature of which is 286 km./sec. The fact that the center appears to lie not far from the center of the galactic system and that the radius of curvature is almost exactly the amount assumed for the speed of rotation of the galaxy in recent studies, tends to support the idea that the asymmetry in stellar motions is the resultant of solar motion in our local cluster and rotation of the galaxy as a whole. Various tests have been made for effects which might be interpreted as results of galactic rotation. If there is galactic rotation, preferential motion should take place along a line directed toward the center of the galaxy. It is found that the direction of the galactic center indicated by the preferential motions from velocity groups varies regularly from 353° in the case of the slow moving stars to 320° for velocities greater than 100 km./sec., but that, if the observed preferential motions be considered as the resultants of true motions along the direction of the galactic center and solar motion in the local cluster, this progression is wiped out and the direction of the

center is $l = 3^\circ$. According to the rotational theory the ratio of the axes in the velocity ellipsoids should be 0.71. Among the stars of different types is found a range from 0.63 for the A stars to 0.82 for the M giants, the result from the general solution being 0.72. Assuming Oort's value for the rotation at unit distance $A = 0.019$ km./sec. parsec, the angular velocity of rotation becomes $\omega = 0.040$ km./sec. parsec $= 0''.0084$, from all the stars, or $0''.0072$, leaving out the B and Mg stars, for which the ratios of the axes are comparatively large. In the two cases the rotational coordinate B is -0.023 or -0.015 km./sec. parsec, values in good agreement with results based upon other studies of galactic rotation. Values of the solar speed have been determined from galactic zones of 15° in longitude between latitudes $\pm 50^\circ$ for groups according to velocity and distance. These show the double maxima and minima to be expected upon the rotational theory and the curves through them may be represented by the equation $V = k \cos \lambda + a \sin 2(l-l_0) + b \cos 2(l-l_0)$. Application of this formula in the solution involving all the stars reduces the range in the values of the solar speed in the different galactic zones from 9.0 km. (13.6 to 22.6) to 2.0 km. (16.5 to 18.5). In general it may be said that the evidence so far secured is definitely favorable to the theory of galactic rotation. Further investigation is in progress.

Raymond has continued his study of the more general characteristics of the distribution of space velocities based upon moments of the third and fourth orders. The material was split into two groups, one containing stars to the sixth magnitude and the other the fainter stars. This was deemed advisable because the proper motions of the Preliminary General Catalogue are complete only to that magnitude. The fainter stars were selected primarily because of striking proper motion and their space motions, therefore, average high for stars of their magnitudes. The brighter group may be considered as representative of the normal mixture of all stars, the fainter group of stars of high velocity.

The direction of the large velocities was found as the direction (A_4, D_4) in which the mean cube velocity is a maximum, and also as (A_s, D_s) in which the skewness, $sk = \bar{\xi^3}/6\sigma^3$ is a maximum, where ξ is the component of velocity in an arbitrary direction and σ the dispersion of the velocities in that direction. These two do not lead to the same result, since the point defined by the second will be drawn away from the first, in the neighborhood of which $\bar{\xi^3}$ changes but slowly, toward regions where the denominator is smaller. The direction in which $\bar{\xi^3}$ is a maximum are

	Bright	Faint	All
A_4	93°	143°	136°
D_4	-13	-60	-55
Max	56275	725060	190921
**	3265	946	4211

The direction in which the skewness, as defined above, is maximum are

A_s	184°	131°	150°
D_s	-34	-59	-58
sk	1.375	0.879	1.135

The group "All" is dominated by the large proper motions to a greater degree in the matter of skewness than in the solar and preferential motions, because the cube velocities are determined for the most part by the few large ones. The group "Faint" has a smaller skewness than the others, because the large motions are so one-sided in distribution that they go largely to increase the apparent solar motion. The point (A_4, D_4) probably represents the real tendency of high velocities more closely than (A_5, D_5), though the mean of the two seems to vary less between the three groups than does either. The point (A_4, D_4) corresponds to a grouping of apices of high velocity stars near Vertex I of the preferential motion, which with still higher velocities moves southwardly along the galaxy toward the intermediate pole (A_2, D_2) of preferential motion.

STELLAR WAVE-LENGTHS

Albrecht has completed an investigation of the spectrum of γ Geminorum based upon spectrograms taken with a dispersion of three prisms. After a preliminary study of 233 spectrum lines had shown that the majority of the lines which could be readily identified are enhanced lines, mostly of the first stage of ionization, the spectrograms were studied in greater detail, special emphasis being placed upon the probable presence or absence of all enhanced lines within the region covered on the spectrograms. For this purpose the available lists of enhanced lines were supplemented by lists of the strongest spark lines for 48 elements. The spectrograms of γ Geminorum were examined in detail for these enhanced and strong spark lines and for many strong arc lines, in order that a fair estimate might be obtained of the presence or absence of the lines of any element in the stellar spectrum. This procedure was expected to provide the most reliable method of ascertaining the probable simplicity or multiplicity of the stellar lines, especially the stronger ones, which might serve as standards of wave-length for stars with class A spectra.

Wave-lengths on the international system were determined for more than 900 lines between 4250 and 4723. Aside from strong $H\gamma$ and Mg II at 4481 the lines of Ti II, Fe II and Cr II dominate this stellar spectrum. The lines of Sc II likewise are present. Other elements which seem to be represented, though with lower intensity, are: Fe I, Ti I, Cr I, Al II and III, Mn II, Sm II, Ba I and II, La II, Bi I and II, Ni I and II, Mo II, V II, and several spark lines of V I, six of the stronger spark lines of Rb, and five of the stronger spark lines of Ru. The following are probably present: two strong spark lines of Pb, Nd II, Sr II, Zr II, Y II, Th II, Ce II, Cs II, Pr II, Eu II, Sb, and Er. Pt, As, Os and Yb seem to be absent. Gd II, Zn II, Te, Sr I, W, Tb, Cn II, Nb, Ir, Ca, Co, Ag II, Cd, S, and Cl proved to be indeterminate, due in part to the fact that their lines are in approximate coincidence with lines of other elements. Particularly where only a small number of lines of an element are available, a few such coincidences render a decision either difficult or impossible. Among the so-called "predicted" Fe lines, which are not present in laboratory spectra but which had been predicted on the basis of recent theory, 18 seem to be present in the spectrum of γ Geminorum.

These wave-lengths are offered as a contribution toward the problem of establishing a list of normal wave-lengths for the lines observable in class A spectra. The investigation in this manner of a typical star of each spectral class seems essential to an intelligent assignment of normal wave-lengths to measured lines for determinations of radial velocity and for the solution of various related problems.

STAFF

During the past year Mrs. Lillian F. Blanchard retired on account of disability and Mrs. Helen M. Smith resigned. Mrs. Flora W. Guffin was appointed to fill Mrs. Blanchard's position. Otherwise the personnel of the staff remains the same as it was last year.

MOUNT WILSON OBSERVATORY

GEORGE E. HALE, HONORARY DIRECTOR

WALTER S. ADAMS, DIRECTOR

FREDERICK H. SEARES, ASSISTANT DIRECTOR

An event of great importance in its bearing on the present and future plans of the Observatory was the action of the International Education Board on October 18, 1928, in providing funds to the California Institute of Technology for the construction of a 200-inch reflecting telescope. The gift was made on the understanding that a detailed plan would be worked out for cooperation between the staffs of the California Institute and the Mount Wilson Observatory of the Carnegie Institution of Washington in the design, construction and operation of this great instrument. A brief statement of the origin and history of this project should be of interest in any report of the activities of the Observatory.

One of the chief concerns of Dr. Hale, Honorary Director of the Observatory, has been the necessity for developing its instrumental facilities and methods in order to keep pace with the needs of current research. In cases which involve very heavy expenditures for individual instruments it can not be expected that the available financial resources of the Carnegie Institution will permit all desirable additions to be made. Accordingly when the need for a larger reflecting telescope for the solution of important problems became increasingly evident Dr. Hale made a serious effort to secure the necessary funds from donors outside of the Institution. While he doubted the advisability of attempting an immediate increase in aperture from the 100 inches of the Hooker telescope to the 25 or 30 feet advocated by Pease and Ritchey in recent papers, he felt that a decided increase in light-gathering power might prove feasible, both from the structural and the financial standpoint. The resolution and detailed study of spiral nebulae, the investigation of stellar spectra with very high dispersion, and further attacks on the astrophysical aspects of the problem of the constitution of matter are typical illustrations of the numerous researches that call for more light than even the 100-inch Hooker telescope can concentrate.

A letter accompanied by a copy of Dr. Hale's article on "The Possibilities of Large Telescopes," sent to the President of the International Education Board led to several conferences between Dr. Hale and Dr. Rose, who proved to be greatly interested in the project. His interest was based chiefly upon the successful cooperation of the Mount Wilson Observatory and the California Institute of Technology in Pasadena, and his belief that the provision of additional means for furthering this cooperation might lead to many new advances in astronomy, physics, and chemistry. The plan of providing a large telescope for the California Institute, and the assurance of intimate cooperation with the Carnegie Institution of Washington and the Mount Wilson Observatory promised to lead to the accomplishment of the projects in view. The plan thus considered provided for the use of the telescope by certain members of the research staffs of both the Observatory and the Institute, and for their joint utilization of many closely related facilities. The equipment of the proposed Astrophysical Observatory of the

California Institute is therefore intended to supplement and not to duplicate that of the Mount Wilson Observatory, and to afford means for the development of graduate study and research by advanced students.

On the recommendation of President John C. Merriam, the Executive Committee of the Carnegie Institution of Washington acted upon a request from the California Institute of Technology and promised full cooperation in all phases of the undertaking, and Dr. Adams, Director of the Mount Wilson Observatory, gave most cordial assurances of interest and support. The Board of Trustees of the California Institute also welcomed the plan and agreed to meet the expense of operating the Observatory if funds for its construction could be provided.

During the year preliminary investigations, including that of the mounting of the telescope, the selection of a site, the design of the optical shop, instrument shop and astrophysical laboratory to be located on the grounds of the California Institute, the material and method of manufacture of the 200-inch mirror, and many optical and mechanical problems connected with the telescope, have been carried on under the direction of the Observatory Council of the Institute of which Dr. Hale is Chairman. Through the cooperation of the Carnegie Institution of Washington, Dr. John A. Anderson of the staff of the Mount Wilson Observatory has been detailed to serve as executive officer in direct charge of design and construction, and Dr. Francis G. Pease and Dr. Sinclair Smith, also of our staff, have been placed on a basis which allows them temporarily to devote a portion of their time to this work. An Advisory Committee, which includes, among other leading scientists who are frequent visitors to Mount Wilson, two Research Associates of the Carnegie Institution, Dr. A. A. Michelson of the University of Chicago and Dr. Henry Norris Russell of Princeton University, has aided the Observatory Council and Dr. Anderson in determining matters of policy and in studying many of the problems involved. The members of the Mount Wilson staff who are also members of the Advisory Committee are the Chairman, Dr. Walter S. Adams, Director of the Mount Wilson Observatory, Professor Frederick H. Seares, Assistant Director, and the Secretary, Dr. Edwin Hubble. Many other astronomers, physicists, chemists, meteorologists and engineers at different institutions have been called upon for assistance and advice.

The Observatory has aided in numerous other ways in the development of the plans for the 200-inch telescope. Three of the members of our staff with a wide experience in observing conditions, Messrs. Ellerman, Hubble and Humason, have devoted a considerable amount of time to the investigation of possible sites in Southern California and Arizona, carrying on quantitative measurements of the seeing with small telescopes. In the optical shop the training of additional men for the extensive work involved in the figuring of mirrors for the 200-inch telescope has been commenced by our opticians, and in addition work has been begun upon several fused quartz disks sent for experimental purposes by Dr. Elihu Thomson of the General Electric Company, under whose direction it is hoped that a 200-inch fused quartz disk will be successfully constructed.

Among the numerous investigations carried on during the year, especial reference may be made to two which illustrate in a striking way the far-

flung range of modern astrophysical research. The first of these is the remarkable character of the results found by Hubble, Humason and Pease for the apparent velocities of the very distant nebulae, and the outlook they afford upon the nature of the universe of space and time. Simply as results of observation, the discovery of apparent velocities of recession ranging upward to nearly 8000 km. a second is of great interest, but much more significant and of fundamental importance to our conceptions of the universe is the relationship established with a considerable degree of certainty between the magnitude of these velocities and the distances of the nebulae observed. This is of a simple linear character such that one nebula twice as far away as another will show twice as great an apparent velocity. It may well prove that this relationship will ultimately afford the most accurate means for deriving the distances of the extremely remote nebulae. At present, however, its chief interest lies in the fact that it affords an apparently unique criterion for use in forming a judgment upon the two or three great hypotheses of the space-time structure of the universe as a whole. The mathematical complexity of the subject is enormous, and it is still uncertain what portion of the large apparent velocities observed is to be ascribed to actual motion in the usual sense, and what part to the effects of the properties of space. As the most remote objects of which we have any knowledge, however, these nebulae with the phenomena associated with them seem to be the only source upon which we can depend for information regarding what occurs to light as it passes through the depths of space and past the great masses of matter constituting the stars.

At nearly the other extreme from investigations of the nebulae may be placed the laboratory observations of Babcock and King which, under the skilful theoretical treatment of their associates at the University of California, Messrs. Birge, Dieke, Giauque and Johnston, have led to the extremely important discovery of isotopes for two of the most fundamental elements, oxygen and carbon. The molecules of both of these elements have heretofore been considered as existing in but a single form, with masses of 16 and 12, respectively. The recent results show in the case of oxygen the presence of an isotope of mass 18, and in that of carbon an isotope of mass 13. The observational evidence for oxygen was afforded by the discovery of a new band in the spectrum of atmospheric oxygen which on careful analysis proved to be in the exact position to be expected from theory if oxygen consists of two isotopes, one of mass 16 and another, much less abundant, of mass 18. Similarly in the case of carbon, spectra taken with the electric furnace showed a faint band which corresponds very closely to that which should be given by a C^{13} — C^{12} molecule. Additional evidence from a variety of sources places both identifications beyond question and thus establishes a discovery of the very first order in the fields of physics and chemistry. It is interesting to note that the presence of the band now known to be due to the isotope of carbon was recognized in the spectra of certain N-type stars more than 25 years ago, although in the complete absence at that time of any theory of band or line spectra no suggestion could be made as to its origin. The value of cooperative study by those engaged in several fields of research is illustrated in a most striking way by the successful outcome of these two investigations.

STAFF

Dr. George E. Hale, Honorary Director of the Observatory, has continued his observations of solar phenomena with the spectrohelioscope and other equipment at the Solar Laboratory. He has devoted much time to plans relating to the 200-inch telescope and the relationship of the Mount Wilson Observatory to this important project. Dr. Walter S. Adams, Director, has carried on investigations in stellar spectroscopy. Professor Frederick H. Seares, Assistant Director, has shared in the administrative work of the Observatory and has continued his photometric and statistical researches.

Dr. John A. Anderson has given about half of his time to duties connected with his position as executive officer of the project of the 200-inch telescope. He has also extended his studies of the spectra of metals and gases in laboratory sources of exceptional types. Dr. Arthur S. King, Superintendent of the Physical Laboratory, has made extensive investigations of the spectra of rare earths in the electric furnace and recently has made a special study of the new isotopic bands of carbon. Dr. Charles E. St. John has analyzed the results of the rich material contained in his *Revision of Rowland's Table of Solar Spectrum Wave-Lengths* and has commenced quantitative measurements of the intensities of a selected list of solar lines. Mr. Harold D. Babcock has continued with marked success his photographic investigation of the infra-red solar spectrum and has added to his results on the bands of atmospheric oxygen which led to the discovery of the isotope of oxygen. Dr. Paul W. Merrill has studied the physical interpretation of the spectra of numerous stars, giving especial attention to those showing emission lines. Dr. Edwin Hubble has obtained important results in continuing his program on the brightness, distance and dimensions of extra-galactic nebulae. Professor Alfred H. Joy, Secretary of the Observatory, has carried on researches in stellar spectroscopy with especial reference to the spectra of variable stars. Dr. Seth B. Nicholson has remained in charge of the program of solar observations and has studied sun-spot polarities and the relationship of solar activity to magnetic storms. Dr. Francis G. Pease has devoted half of his time to problems connected with the design and plans of the 200-inch telescope. He has continued observations with the 20-foot interferometer and has aided in the design of much of the apparatus constructed during the year. Dr. Adriaan van Maanen has been engaged in photographic measurements of stellar parallax and proper motion. Dr. Edison Pettit has carried on a number of radiometric investigations, dealing especially with ultra-violet solar radiation and the character of the radiation from the moon. Dr. Roscoe F. Sanford has continued his measurements of stellar radial velocities and his studies of the orbits of spectroscopic binaries. Dr. Gustaf Strömberg has shared in the stellar spectroscopic observations and has made statistical researches on the motions and absolute magnitudes of the giant K-type stars. Mr. Milton Humason has given much of his time to the important problem of the radial velocities of the fainter extra-galactic nebulae. He has also added to his material on the spectral classification of the faint stars in the Selected Areas. Mr. Ferdinand Ellerman has taken part in the solar observations and has carried on much of the photographic work of the Observatory.

Both Mr. Ellerman and Mr. Humason have made observations of seeing conditions at mountain sites in connection with the question of the location of the 200-inch telescope. Dr. Sinclair Smith has divided his time during most of the year among investigations in the physical and seismological laboratories and certain problems relating to the accessory instruments of the 200-inch telescope. Dr. Theodore Dunham jr. joined the staff on January 1 and has been engaged in a study of the methods of photometry of spectral lines with especial reference to stellar spectra. Mr. Joseph Hickox has been the regular solar observer on Mount Wilson throughout the year.

In the Computing Division, Mr. True Robinson and Miss Elizabeth Sternberg have carried on measurements of sun-spot areas and positions and have classified and collected the observations of sun-spot polarities. Mr. Edward F. Adams has measured photographs of the solar spectrum, making a special study of the displacements of lines at the edge of the sun. Miss Louise Ware has carried on the work of the large registering microphotometer, using the instrument for measurements of the general magnetic field of the sun and the contours and intensities of solar and stellar spectral lines. Miss Mary C. Joyner has assisted Mr. Seares in the photometric measurements of stars and the preparation of the Mount Wilson Catalogue of the Selected Areas. Miss Myrtle L. Richmond has given her time to the measurement and reduction of radiometric observations. Mrs. Hannah M. Marsh has aided in the determination of stellar parallaxes and proper motions. Mr. William H. Christie joined the Division on January 15 and has been engaged in the measurement of stellar spectrograms. He has also taken part in spectroscopic and direct photographic observations. Miss Cora G. Burwell has continued her measurements of the wave-lengths of lines in stellar spectra and has studied their identification and changes with variations in light. Miss Elizabeth MacCormack and Mrs. Katherine Kaster have carried on measurements of radial velocity and computations relating to stellar motions. Miss Ada M. Brayton has given most of her time to computations relating to determinations of absolute magnitudes and parallaxes of stars. Mr. Wendell P. Hoge has aided Mr. Babcock in his laboratory observations and in the determination of the wave-lengths of infra-red solar spectrum lines. Miss Elizabeth Connor has remained in charge of the library and has assisted in the editorial work of the Observatory publications.

Dr. A. A. Michelson, Research Associate of the Institution, spent a portion of the summer of 1928 in Pasadena, conducting experiments on methods for improving his determination of the velocity of light. He returned to Pasadena in June 1929. Dr. Henry Norris Russell, Research Associate, spent three of the winter months at the Observatory and carried on investigations on the composition of the sun's atmosphere and the abundance and state of ionization of the elements composing it. As in previous years, his lectures before the members of the staff were most suggestive and valuable. Sir James Jeans has continued his advice and cooperation on cosmological problems. Dr. Charles G. Abbot, Secretary of the Smithsonian Institution, carried on solar observations during the summer of 1928 at the Smithsonian observatory on Mount Wilson. In August and September he applied successfully a radiometer of his own design and construction to the measure-

ment with the 100-inch telescope of the spectral energy of stars. Dr. Fred E. Wright, of the Geophysical Laboratory of the Institution, spent two of the autumn months in Pasadena and at Mount Wilson. He made numerous observations of the moon during his stay and carried on further studies of methods of investigating the nature of the lunar surface. A meeting of the Committee on the Study of the Surface Features of the Moon, of which Dr. Wright is Chairman, was held on Mount Wilson in September. Dr. Frank E. Ross of the Yerkes Observatory conducted photographic observations on Mount Wilson during a portion of the summer of 1928, and Dr. John C. Duncan, Director of the Whitin Observatory of Wellesley College, carried on both direct photographic and spectroscopic work with the large reflectors during the same period. Dr. Frederick C. Leonard, of the University of California at Los Angeles, has continued throughout the year observations of the spectra of visual double stars with the 60-inch reflector. Dr. Theodore Dunham jr. remained at the Observatory as National Research Fellow until January 1, at which time he joined the staff. He continued his stellar spectroscopic observations and his study of spectrophotometric methods. Dr. Harvey E. White of Cornell University during the summer of 1928 made a study of some of the stronger lines of ionized praseodymium, using the 75-foot spectrograph on Mount Wilson to analyze their complex structure. Dr. Albrecht Unsöld, International Research Fellow, spent most of the year at the Observatory and completed several investigations of great interest on the contours of solar lines and the conclusions to be drawn from them regarding physical conditions in the sun's atmosphere. Dr. Nicolas Perrakis of the Observatory of Athens returned to Europe in December after a year spent in general solar observations. Dr. C. D. Shane, Professor of Astronomy at the University of California, carried on solar spectroscopic observations on Mount Wilson during June 1929 with a view to developing a new method for measuring line-intensities. Dr. P. ten Bruggencate of Göttingen, Germany, spent two of the winter months in Pasadena, and carried on direct photographic and spectroscopic observations with the 60-inch reflector, giving particular attention to certain Cepheid variables and stars in clusters. Mr. Robert S. Richardson has spent several months at the Observatory, engaged in the measurement and identification of lines in sun-spot spectra. He has also assisted in the solar observations on Mount Wilson. Mr. Sidney R. Pike, International Research Fellow from Leeds, England, came to the Observatory in September to undertake observational and theoretical investigations in solar spectroscopy. Within a few weeks he was stricken by a severe illness. His death in November brought to a close a life which gave promise of brilliant contributions to physical science.

Three of the members of the Staff of the Observatory, Messrs. Hubble, King and St. John, attended the meeting of the International Astronomical Union held at Leiden in July 1928, and Hubble and St. John presented reports before the scientific committees of which they were chairmen. Following the Leiden meeting they visited scientific and technical centers in Germany, Holland and England in the interest of questions connected with the 200-inch telescope and its equipment. Dr. St. John also attended the

General Assembly of the International Research Council at Brussels as a delegate of the National Research Council of the United States.

SUMMARY OF THE YEAR'S WORK

Observations of sun-spot activity made regularly throughout the year indicate a slight falling off in the number of spots as compared with 1927. A total of 362 groups was observed in 1928 as against 424 in 1927. The mean latitude of the spots decreased from $15^{\circ}5$ in 1927 to $13^{\circ}6$ in 1928, thus providing additional evidence that the maximum of the cycle is past. The maximum appears to be of the broad rounded type resembling that of 1905, and lower and less pronounced than that of 1917.

Measurements of the polarity and intensity of the magnetic field in sun-spot groups were made on 305 days in 1928 by Nicholson, Ellerman, Hickox and Richardson. Out of 310 groups observed only 8 were found to be irregular in the sign of their magnetic fields.

Other solar observations have included photographs of the sun made directly and with the spectroheliograph on all clear days, special studies of disturbed areas with the spectroheliograph, visual observations and measurements of rapidly moving prominences and filaments by Hale with the spectrohelioscope, and comparisons by Nicholson of different types of solar disturbances with variations in terrestrial magnetism. During the year plans have been worked out by Hale for cooperative investigations of the sun with the spectrohelioscope at a series of observatories distributed around the earth, and four spectrohelioscopes constructed in our instrument shop have been sent to astronomers taking part in this project.

In continuation of his photographic study of the infra-red solar spectrum, Babcock has succeeded with the aid of improved instruments and color filters in measuring the wave-lengths of over 350 lines between λ 9867 and λ 11,634. The accuracy of the results makes it possible to identify many important lines in this region, including those of potassium, magnesium, calcium, and other light elements. Carbon in the atomic state seems to be represented by an important multiplet near λ 10,700. A study of the contours of the Paschen lines of hydrogen should lead to valuable results. The total number of solar lines measured by Babcock in the region to the red of the limit of Rowland's table at λ 7330 is now about 2500.

Further studies have been made by Babcock of the bands of atmospheric oxygen, the analysis of which, based on his measures, led Giauque and Johnston to the discovery last year of an isotope of oxygen of mass 18. Two new bands have been found, one belonging to the sequence of bands due to the $O^{16} - O^{18}$ molecule, while the other has been interpreted by Giauque and Johnston as due to an isotope of mass 17. An estimate of the relative abundance of the various atoms, based upon the method of different lengths of air-path, indicates that the O^{16} atom is 1250 times as abundant as the O^{18} atom, and 10,000 times as abundant as the O^{17} atom. Of very great importance is the application of this spectroscopic method to the so-called "packing effect," which determines the amount of energy set free as high-frequency radiation when light atoms unite to form a heavy atom with a mass slightly less than that of the sum of its components.

St. John has continued his measurements of the rotation period of the sun, and of the residual displacements of a selected list of lines at points between the center and limb of the sun after elimination of the relativity effect. Changes in intensity and contour are also being investigated as a part of an extensive program on the spectrophotometry of solar lines.

Dr. Unsöld has made a study, based on line-contours and the theory of radiative equilibrium, of the results given by the spectroheliograph in light of different portions of the H and K lines of calcium. He arrived at formulæ which give the intensity of the emergent light as a function of the temperature and of the coefficients of scattering and absorption in the solar atmosphere. An approximation to actual solar conditions is found by assuming that the reversing layer consists of two strata to which different constants may be assigned; and the origin of the narrow central K₂ line in the upper chromosphere is explained on this assumption.

From a further investigation of the contours of lines of Ca II and Ba II resembling resonance lines in character, Dr. Unsöld finds that for excitation potentials up to 1.7 volts Boltzmann's relation gives the correct proportion of atoms in the highly excited states within the accuracy of measurement. This makes it probable that the deviations from the formula found in stellar atmospheres are due to an oversupply of highly excited atoms rather than to a deficiency of those in a low state of excitation.

Dr. Russell, using modern physical and astrophysical data and theory, has made an important study of the relative abundance of different elements in the solar atmosphere. He finds that when the excitation potential of the strongest lines of an element in the observable part of the spectrum is less than about 5 volts, this element nearly always shows lines in the solar spectrum, but only rarely when this limit is exceeded. Hydrogen is a notable exception. About 50 per cent of the atoms with an ionization potential of 8.3 volts are ionized. Tables have been derived showing the relative abundance of 56 elements and 5 compounds, and these indicate that six elements—sodium, magnesium, silicon, potassium, calcium and iron—contribute 95 per cent of the whole mass of the solar atmosphere. The number of metallic atoms above a square centimeter of the surface is 8×10^{20} , 80 per cent of which are ionized. The elements of even atomic number are, on the average, 10 times as abundant as those of odd number. A final estimate of the composition by volume of the solar atmosphere is: hydrogen, 60 parts; helium, 2; oxygen, 2; metallic vapors, 1; and free electrons, almost wholly due to ionization of the metals, 0.8.

The past year completes a period of 5 years during which observations of the ultra-violet radiation of the sun have been obtained by Pettit. The general trend of the monthly averages follows the curve of sun-spot numbers except for an interval in the summer of 1928 when a depression in the ultra-violet curve corresponded to a rise in sun-spot frequency. The highest monthly average of the ratio at $\lambda 0.32\mu$ to $\lambda 0.5\mu$ was 1.57 for November 1925, and the lowest, 1.12, for September 1928.

Pettit has also measured in Pasadena the amount of sky radiation at $\lambda 0.32\mu$ at the summer and the winter solstices, and has studied the limits of the ultra-violet spectrum of the sun and sky. With an exposure time of 2 hours on sunlight, through a quartz monochromator crossed with a 1-meter

concave grating, lines of wave-length slightly shorter than $\lambda 0.29\mu$ have been recorded photographically.

Lunar observations have included direct photography of the moon's surface and of the earth-lit moon, and visual studies of special features. Pettit and Nicholson have completed the reduction of their measurements of lunar radiation made since 1922 and have deduced the law of the distribution of heat across the disk of the full moon. Owing to the roughness of the lunar surface this departs considerably from the theoretical law. The radiometric magnitude of planetary heat at the sub-solar point on the moon is $+1.74$ per square second of arc. This would correspond to a temperature of 370° K. Observations of the conducted heat which were made by Pettit and Nicholson at the lunar eclipse of June 14, 1927, gave a value of $0.1 \text{ cal. cm.}^{-2} \text{ min.}^{-1}$. Dr. Epstein has used this result in a theoretical consideration of the materials composing the lunar surface and finds that it corresponds most closely to volcanic ash or pumice. A more extensive series of measurements made by Pettit at the lunar eclipse of November 26, 1928, gave results in good agreement with the previous values.

Direct photographs of nebulae made by Pease and Dr. Duncan have resulted in the discovery of several novae and variable stars. Two such stars found by Pease in the Dumbbell nebula are of especial interest.

Hubble has completed and published his investigation of the distances and dimensions of the three large extra-galactic nebulae of the northern sky in which individual stars can be studied in detail. He is now giving his attention to a selected list of spirals and irregular nebulae containing stars which may provide criteria for the measurement of distance and thus increase the material available for statistical treatment of the more distant nebulae. The systematic survey of small nebulae by Hubble, the purpose of which is the study of the distribution of nebulae as a function of galactic latitude and a more accurate determination of the density function, is now about 90 per cent completed.

A series of measurements by van Maanen of the relative motion of the nucleus of the nebula N. G. C. 4051 made on photographs covering an interval of 11 years gives values of $+0''.005 \pm 0''.001$ in right ascension, and $+0''.017 \pm 0''.0015$ in declination. The r -component of the motion, $0''.014 \pm 0''.0015$, if comparable with the radial velocity of 650 km./sec. , would yield a parallax of about $0''.000065$. Although the nebula appears to have definite spiral structure, its spectrum is of the planetary nebula type and the absolute magnitude derived by van Maanen is in good agreement with values previously found by him for the central stars of planetaries.

Some very important and remarkable results have been obtained for the apparent radial velocities of extra-galactic nebulae by Humason and Pease. Three nebulae in the Coma Berenices cluster near the pole of the Milky Way give values of $+4700$, $+7300$, and $+7800 \text{ km./sec.}$, respectively. A nebula in a cluster in Pegasus gives $+3800 \text{ km./sec.}$, and the three nebulae, N. G. C. 3227, 4051 and 6359, which are not members of clusters, have apparent velocities of $+1150$, $+650$ and $+2800 \text{ km./sec.}$ These results bear directly upon de Sitter's theory of the space-time world and Hubble's correlation between distance and apparent radial velocity. In general they tend to confirm Hubble's linear relationship of an increase of about 500 km./sec.

for each 1,000,000 parsecs of distance, a result which if fully established would provide a most valuable means for deriving the distances of the remote nebulae. The full solution of the problem of the interpretation of the large positive displacements of the spectral lines in a de Sitter space-time world is subject to extraordinary mathematical difficulties and must await further investigation.

A provisional estimate by Hubble of the distance of the Coma Berenices cluster of nebulae indicates a value of the order of 50,000,000 light years. This result is based upon a comparison of the mean apparent photovisual magnitude of the cluster nebulae with the previously determined absolute magnitude (-15.2) of nebulae in general.

In continuation of his measurements of parallaxes of stars, van Maanen has derived values of $+0''.213$ for Wolf 562 and $+0''.084$ for Ross 136. The latter has an absolute magnitude of $+14.2$. A faint star $4''$ distant from the central star of the large planetary nebula N. G. C. 246 is found to have the same proper motion as the nebula. Its color-index corresponds to a spectral type of about K, and the possibility that these stars form a physical system is of great interest and will be investigated.

First-epoch photographs for the measurement of proper motions have been obtained by van Maanen for over 100 fields. Many of these are for Cepheid variables. Values of the proper motions of 5 planetary nebulae have been obtained which indicate that the distances of the nebulae can hardly be less than those of the comparison stars ranging in magnitude from 11.5 to 13.5. A comparison of 21 fields in Selected Areas has been made by van Maanen, using recent photographs in conjunction with those made nearly 20 years ago. About 34,000 stars of magnitudes between 10 and 20 have been compared, and 59 stars were found to have proper motions between $0''.049$ and $0''.451$ annually. The results indicate that the percentage of stars with considerable proper motion, as well as the size of the proper motions themselves, increases with galactic latitude.

The Mount Wilson Catalogue of the Selected Areas giving the photographic magnitudes of 67,941 stars is now in press. Seares and Miss Joyner are at present engaged with the reduction of the photovisual magnitudes in 42 of the Selected Areas. The scale is determined independently for each area, and comparisons with the pole and with adjacent areas provide data for reduction of the magnitudes to the international zero point. Reductions for the zone at $+45^\circ$ are now complete, and the values of the color-indices derived from the exposure-ratio photographs have been found to be in good general agreement with those obtained from the magnitudes of the stars.

Pease has carried on observations of a few stars with the 20-foot interferometer, although no large amount of time has been given to this work in view of the approaching completion of the 50-foot interferometer. Measurements of the diameter of Mira at the maximum of 1928 gave a value of $0''.047$ as compared with a previous result of $0''.056$.

In the field of stellar spectroscopy much attention has been given during the year to the development and improvement of the coudé spectrograph and the Cassegrain instruments in use with both of the large reflectors. New camera lenses have been secured, a quartz spectrograph has been constructed, and an additional low-dispersion instrument for use on faint stars

and nebulae is being designed. Dunham has given much time to the development of methods for obtaining standardizing spectra to be used in the photometry of the stellar spectra photographed with the coudé instrument. A step-wedge with 12 sections of increasing opacity has been constructed for this purpose.

About 1,500 stellar spectrograms have been obtained during the year. Most of these have been used for determinations of radial velocity and absolute magnitude, while others have formed the material for physical studies of the spectra. A catalogue of the radial velocities of 741 stars has been prepared by Adams, Joy, Sanford and Strömberg which gives values for many stars of large proper motion. A comparison of results for stars observed in common with the Lick Observatory shows a good degree of agreement after the application of small systematic corrections. The catalogue includes about 60 stars with velocities exceeding 50 km./sec., and 7 stars with velocities exceeding 100 km./sec. The asymmetry of stellar motions is strikingly shown by the motions of these stars.

Sanford has determined the orbits of the spectroscopic binaries Lalande 17480 and Boss 4865, and has studied the velocity-curves of α Orionis and the Cepheid variable W Geminorum. The velocity-curves of many of the fainter Cepheids and short-period variables and of certain stars of the RV Tauri type have been investigated by Joy. Results showing both velocity and spectral changes with variation in light are nearly complete for W Serpentis, W Virginis, U Sagittae, RS Canum Venaticorum and RT Lacertae.

A special study of the variable R Virginis with a period of 145.4 days has been completed by Merrill and Joy. The spectral type varies from M4e at maximum to M8 near minimum. The velocity-curve derived from the absorption lines resembles the light-curve, but that from the bright hydrogen lines is entirely different, the maximum negative velocity, -40 km./sec., occurring 20 days after maximum of light, and the minimum negative velocity, -25 km./sec., 40 days before maximum of light. The low-temperature lines of iron, magnesium and other elements which appear in emission in the spectrum of δ Ceti are absent or weak in R Virginis.

More than 160 bright lines have been measured by Merrill and Miss Burwell in the spectrum of the Be star B.D. $+11^{\circ}4673$, nearly all of which vary in intensity and position. The hydrogen lines are always bright and conspicuous, while the helium lines which were absorption lines in 1915 became bright in 1921 and have remained so since that time. First-stage ionization is represented by lines of Al, Si, Ti, Cr, Fe, Mg, and N, and second-stage ionization by lines of Al and Si. Lines of Si IV are also present. Forbidden lines of Fe II and N II, including some of the nebular lines, are well marked.

Humason has completed the classification of the spectral types of faint stars in 89 of the 115 Selected Areas under investigation, and Dr. Leonard has continued the observation and classification of the spectra of the fainter components of visual binary systems. Additional stellar spectroscopic investigations have included observations of spectra in the region $\lambda 7000$ — $\lambda 8500$, and of the detached lines of Ca II and Na I, by Merrill; measurements of high-dispersion spectrograms of α Persei and other bright stars by Dunham, Adams and Christie; studies of the radial velocities of β Cephei and δ Aquilae

by Dr. Duncan; and the discovery by Pease of a star with the spectrum of a planetary nebula in the globular star cluster Messier 15.

Dr. Abbot, Secretary of the Smithsonian Institution, secured during August and September 1928 successful measurements of the spectral energy of 18 stars and of the planets Mars and Jupiter. He used for the purpose a special radiometer of his own design enclosed in a fused quartz tube, optically figured. Although the period of swing of the vane system was only about 1.5 seconds, the results showed an average probable error of about 10 per cent of the deflection measured.

Determinations of absolute magnitude and parallax by the spectroscopic method have been continued by Adams, Humason and Joy, and results have been partially completed for nearly 4,000 stars. Lines additional to those used in the earlier work have been included in order to strengthen the weight of the determinations, and the entire material is being reduced to a homogeneous system. A special study has been made of 80 Cepheid variables with periods between 1.6 and 45.2 days, in an attempt to obtain correlations between absolute magnitude, spectral type and period. Absolute magnitudes derived by extrapolation from the reduction tables for normal giant stars of similar spectral types show satisfactory agreement with the values given by trigonometric parallaxes and a very close correlation with spectral type. They are, however, about one magnitude fainter systematically than the absolute magnitudes derived from the period-luminosity relationship. The determination of the reference point of the system will probably have to await measures of proper motion and radial velocity for many more of these stars.

Strömberg has developed and applied to the giant M-type stars a method for obtaining the distribution in absolute magnitude without any assumption as to the analytical form of the distribution function. The results indicate the existence of two groups of stars, clearly separated from one another, one with a mean absolute magnitude of about 0, and the other of -2 . The latter may be identified with the super-giant group shown by the spectroscopic results, but the dispersion is less and the relative number of stars is greater than would be anticipated.

The electric furnace has been used by King for a temperature classification of the spectral lines of the rare earths, and in conjunction with the arc and spark to distinguish the lines of their neutral and ionized atoms. In addition, wave-lengths have been measured for 800 lines of neodymium, many of them previously unidentified. A general survey of the region λ 3850 — λ 4700 is under way for europium, gadolinium, terbium, dysprosium and holmium, and many data on these little-known spectra have already been accumulated. Of the ten rare earths thus far studied, those of odd atomic number have lines with hyperfine structure, while the lines of the alternate elements are sharp.

King has also classified according to temperature and ionization many of the stronger lines of hafnium, an element discovered in 1923. The spectra of beryllium, boron, arsenic and tin have been photographed for a study of certain series lines and for improvement of wave-lengths.

The stronger lines of ionized praseodymium are complex. Detailed knowledge of the spacing and intensity of the components is required for an

analysis of the spectrum. A study with high dispersion, begun by Dr. White of Cornell on Mount Wilson in 1928, is being continued in the Pasadena laboratory by Professor Gibbs and Dr. Gartlein, also of Cornell.

The presence of a faint band in the spectrum of carbon near the strong Swan band at λ 4737 suggested to King the possibility of a carbon isotope as the source of the faint band. Tests made in cooperation with Professor Birge of the University of California gave conclusive evidence of the existence of an isotope of mass 13, which was further confirmed by Birge from measurements of lines in the cyanogen bands and in the spectrum of carbon monoxide. Incidentally the investigation settles a long-standing controversy by showing that the Swan bands are produced by diatomic carbon.

By using fused-quartz vacuum tubes of 1 mm. bore, Anderson has extended the study of vacuum discharges to current densities of 3,000,000 amperes per sq. cm. Discharges in excess of 300,000 amperes cause an evaporation of quartz from the inner wall, which is dissociated into silicon and oxygen. The spectrum of the discharge under these conditions shows in the capillary the low-temperature absorption lines of silicon and, elsewhere in the tube, emission lines of the first four stages of ionization. Discharges of 100,000 amperes give in the capillary a continuous spectrum and indicate that a layer of gas 1 mm. thick, at a pressure of 0.1 to 0.2 mm., and ionized sufficiently to carry a current of this density, is opaque.

Anderson's experiments with wire explosions show for all metals except tungsten that the gas evolved is not the small smooth cylinder of expanding vapor naturally to be expected, but an irregular mass with many jets projecting perpendicularly to the direction of the wire. The exceptional behavior of tungsten seems to depend on its high boiling-point. When vaporization of a metal is complete, the resistance is determined by the ionization, which will be slight if the temperature is low. The discharge thus approaches the disruptive character of the spark and the transverse jets, corresponding to the striations of the spark, are conspicuous. For tungsten, however, the temperature of vaporization is so high that the relatively high ionization affords a low-resistance path and no jets are seen.

Experiments by Babcock indicate that the commercial low-voltage neon lamp is a valuable source of comparison spectra for certain elements occurring as impurities in the neon, among them argon, helium, both normal and ionized, and hydrogen. The conditions in 110 and 220-volt lamps are quite different. Numerous lines of molecular hydrogen are present in the 220-volt lamp, but many strong lines are missing. The conditions suggest that those observed are associated with the high-energy levels of the hydrogen molecule.

Much experimental work has been done on the study and development of sensitive devices for the measurement of radiation. Pettit has determined the voltage sensibility-curves and current-intensity ratios for photo-electric cells, both gas filled and vacuum, coated with sodium, potassium and caesium, and has investigated the effect of exposure to the intermittent light from a rotating sector. The galvanometer deflections with the sector interposed are slightly less than the values calculated from the aperture of the sector. The speed of the sector seems to have no important effect.

Pettit has also constructed a number of thermocouples and thermopiles of different types and has studied their characteristics. Smith has given much attention to the development of a sensitive radiometer suited to astronomical work. The most successful form seems to be of the shielded-vane type with vanes of mica, suspended in an atmosphere of neon. The technical difficulties of producing a light mirror of good definition are great, and much experimental work remains yet to be done. Of the substances thus far tried, calcite seems to be the best. For the vanes, mica sheets one wave-length thick seem to be both lighter and stronger than insects' wings. The sensitivity of the best radiometer thus far made is about 4 times that recently used by Dr. Abbot in successful measurements of stellar radiation.

The Foucault knife-edge test is familiar to every optician as a highly sensitive method of examining the figure of a mirror or lens. Anderson and Mr. R. W. Porter have compared this method with one proposed by Ronchi, and find that the latter is equally sensitive and has the advantage that a darkened room is unnecessary.

The ruling machine has been in active use during the year and has produced a number of excellent 4-inch gratings. Several alloys containing a small amount of nickel have been tested for use as blanks; but since very good speculum castings are now available, these will be used for the present.

The fidelity of the thermoelectric microphotometer as a means of determining the variation of photographic density has been demonstrated in a striking way by Pettit. The intensity-curve of a pair of lines was recorded in the usual way. A microphotograph of the same lines was prepared on a large scale. Counts of silver grains shown by the enlargement were made across the lines and combined with the mean diameter of the grains to calculate the curve of varying density. The agreement of this curve with records of the microphotometer is excellent.

One of the important investigations of Dr. Michelson, Research Associate of the Observatory, is the redetermination of the velocity of light. The successful outcome of measures between Mount Wilson and Mount San Antonio over a base line of 22 miles has already been reported. It was hoped that this result might be tested by extending the measures to a station on Mount San Jacinto, 82 miles from Mount Wilson. Preliminary experiments showed, however, that difficult atmospheric conditions would probably prevent satisfactory observations. Attempts to use Santiago Peak, 50 miles distant, led to a similar conclusion. Dr. Michelson has therefore radically altered his plan and proposes to use a short base a mile in length. The beam of light will be reflected back and forth several times in a line of pipe in which the air pressure has been reduced to a point which will insure good definition. Preliminary study indicated the feasibility of this method, and 1100 feet of pipe line are now under construction. If measurements with a section of this length are as satisfactory as anticipated, the line will be extended to the full mile for use in the final observations.

A third series of measures with the large interferometer, made by Pease and Pearson under the direction of Dr. Michelson, confirms the results of the two series reported a year ago in giving a negative result for a possible ether drift. For the present series the light path was increased to 85 feet and the instrument was mounted underground in a room of nearly constant

temperature. The observations were made from the room above through an opening in the floor. A displacement corresponding to a drift as large as 6 km./sec. should have been revealed by the measures.

OBSERVING CONDITIONS

Observing conditions for the year were above the average as regards clear days and nights. Solar observations were made on 312 days, and the records kept in connection with the 60-inch reflector show that it was in use on 300 nights. The hours of actual observation were 2381 as compared with a 17-year mean of 2244.

The winter was exceptionally cold and was characterized by deficient precipitation, the total amount being 20.64 inches as compared with a 25-year average of 31.96 inches. The total snowfall was 46 inches. The maximum temperature was 96° on August 28, and the minimum 14° on April 6. As in most other years of low precipitation, the seeing conditions during the winter months were below the average. Regular meteorological observations for the use of the Weather Bureau have been continued, and special observations of weather conditions have been provided to assist in the operation of the air-mail service across the mountainous area east of Mount Wilson.

Month	Hours of darkness	Hours of observation	No. observations	Observations		
				All night	Part night	None
1928						
July.....	255	240	15	25	6	0
August.....	269	263	6	28	3	0
September.....	295	288	7	27	3	0
October.....	336	203	133	16	12	3
November.....	330	182	148	15	8	7
December.....	346	214	132	17	8	6
1929						
January.....	346	111	235	9	7	15
February.....	308	125	183	7	9	12
March.....	324	134	190	8	11	12
April.....	286	164	122	9	13	8
May.....	266	242	24	20	10	1
June.....	230	215	15	24	5	1
Totals.....	3591	2381	1210	205	95	65
Mean 17 years.....		2244	1350	193	93	79

Between 10,000 and 15,000 persons have seen the 100-inch telescope and the astronomical exhibit during the hours of the day when these are open to the public, and 5,015 visitors have made visual observations with the 60-inch telescope on Friday evenings throughout the year. About 3000 students from high schools and colleges of Southern California are included in these numbers. Mr. Hoge has continued the practice of giving a public

lecture every Friday evening and has supervised the use of the telescope on these occasions.

SOLAR RESEARCH

Daily measurements of the intensities and polarities of the magnetic fields of sun-spots have been made regularly, as in previous years. All sun-spot groups have been classified according to their magnetic characteristics and much attention has been given to active groups and their relation to variations in terrestrial magnetism. Special studies have been made of active prominences. The band spectra in sun-spots have been studied, chiefly with regard to the intensities of the lines and the identification of additional elements in the sun. Considerable work has been done in the photometric investigation of the absolute intensities and contours of lines in the solar spectrum. Systematic observation of the solar rotation and the daily record of the relative amount of ultra-violet light from the sun have been continued.

SOLAR PHOTOGRAPHY

Direct photographs of the sun have been made with the 60-foot tower telescope on 312 days. A marked increase in the quality of these photographs has been obtained by using a yellow color screen and plates coated with an emulsion sensitive to yellow-green light. In addition to the regular spectroheliograms, a special series has been taken in accordance with the plan of cooperative investigation of solar activity. These photographs have been sent regularly to Kodaikanal and other observatories as requested. The following spectroheliograms have been obtained by the observers, Ellerman, Hickox, Nicholson and Richardson:

On the 6.5-inch image, 37 $H\alpha$ -plates with the 5-foot spectroheliograph and 64 $H\alpha$ -plates of individual groups with the 13-foot spectroheliograph.

On the 2-inch image, 313 plates with $H\alpha$, 294 with K_2 , and 325 prominence plates with K.

SUN-SPOT ACTIVITY

Sun-spot observations were made at Mount Wilson on 329 days in 1928, on two of which no spots were seen. May 20 was the first spotless day since August 16, 1925. The activity during 1928 indicates that the maximum of the present cycle occurred during the first half of 1927. The number of groups observed decreased from 424 in 1927 to 362 in 1928, thus falling below the 373 groups of 1926. For the two hemispheres the numbers in 1927 and 1928 were, respectively, northern, 187 and 167; southern, 237 and 195. Although the decrease was more pronounced in the southern hemisphere, this still remained the more active hemisphere. The mean numbers observed daily are given by months in the accompanying table for 1927, 1928 and January to June of 1929. Although the yearly average for 1928 equals that of 1927, the highest monthly mean for 1928, 7.9, was exceeded by that for three months in 1927.

Further evidence that the maximum is past is afforded by the decrease in the mean latitude of the spots from $15^{\circ}5'$ in 1927 to $13^{\circ}6'$ in 1928. At maximum the mean latitude of the spot-zones is usually a little over 14° .

The Wolf Relative Numbers for 1928 are slightly in excess of those for 1927. By itself this might suggest a time of maximum as late as 1928. The exact date can not be set until another year has passed. The present maximum seems to be of the broad rounded type, less pronounced and somewhat lower than that of 1917 and resembling that of 1905. The similarity of alternate cycles is thus again emphasized.

Mean number of sun-spot groups observed daily

Month	Daily number			Month	Daily number	
	1927	1928	1929		1927	1928
January.....	6.5	6.8	5.2	July.....	5.0	6.7
February.....	8.6	6.3	5.9	August.....	3.9	7.9
March.....	7.4	6.9	3.7	September....	6.3	5.9
April.....	8.3	6.9	4.7	October.....	6.0	6.0
May.....	8.1	5.4	5.4	November....	5.6	4.8
June.....	6.1	7.1	8.0	December....	3.9	5.0
				Yearly average	6.3	6.3

In cooperation with the Harvard and Yerkes Observatories, Mount Wilson has supplied observations on 34 days to supplement the record of areas and positions of sun-spots published regularly by the Naval Observatory in the "Monthly Weather Review."

At a joint session of the committee of the International Research Council on Relationships between Solar and Terrestrial Phenomena and the Solar Physics Committee of the International Astronomical Union, of which Dr. St. John is chairman, a tentative scheme of character figures was formulated to serve as an index of solar activity. The data from the cooperating observatories are assembled at Zurich and issued quarterly in bulletins under the auspices of the Union. These bulletins give for each day the character figures representing the activity of the sun as observed in calcium flocculi, bright and dark hydrogen flocculi, the intensity of ultra-violet light, and the Wolf Relative Number of spots. It is hoped that a study of these data will indicate whether sun-spots or some other of these solar phenomena are the best criteria of solar activity, at least in so far as their variation is related to terrestrial phenomena. The published data begin with January 1, 1928, and during the year character figures were estimated here for the calcium flocculi on 422 days and for the hydrogen flocculi on 416 days.

SUN-SPOT POLARITIES

Records of the polarity and intensity of the magnetic field in sun-spot groups were made on 305 days in 1928 with results shown in the table. Regular groups show in the northern hemisphere S (south-seeking), or negative, polarity for the preceding spots, and N polarity for the following spots, while in the southern hemisphere the polarities are opposite. Complex groups, unipolar spots for which there was no indication as to whether they

were preceding or following members of a group, and all unclassified spots are omitted from the table.

Hemisphere	Polarity	
	Regular	Irregular
North.....	144	1
South.....	158	7
Whole Sun.....	302	8
Total.....	310	

TERRESTRIAL MAGNETISM AND SOLAR ACTIVITY

The variations in the magnetic declination and in the intensity of the horizontal component of the earth's magnetic field have been recorded continuously during the year. These records are being compared with those of solar activity in an effort to discover the type of solar phenomenon responsible for magnetic disturbances and to determine the lag between these related phenomena. In studying this problem Nicholson spent a month at the Department of Terrestrial Magnetism in Washington, conferring with members of that department and studying their records.

COOPERATIVE RESEARCH WITH THE SPECTROHELIOSCOPE

Mr. Hale has continued his work with the spectroheliometer, giving special attention to the development of instruments of inexpensive construction and to their use for the nearly unbroken observation of the solar atmosphere at observatories distributed around the world. Six sets of such instruments have been constructed in our instrument shop, four of which have already been sent to the Royal Observatory, Greenwich; the Royal Astrophysical Observatory, Arcetri, Italy; the Observatory of the American College at Beirut, Syria; and the Observatory, Apia, Samoa. Negotiations for the use of the two remaining instruments at suitable longitudes are in progress.

Additional spectroheliometers of the same design have been built by Messrs. Howell & Sherburne of Pasadena for the Commonwealth Solar Observatory, Canberra, Australia; Pomona College Observatory, Claremont, California; Yerkes Observatory, Williams Bay, Wisconsin; the Emerson McMillin Observatory, Ohio State University, Columbus, Ohio; and the Physical Laboratory of Vassar College, Poughkeepsie, New York. Other institutions may also soon order spectroheliometers. Such solar eruptions as give rise to magnetic storms and auroras, many of which have escaped notice in the past, are therefore more likely to be detected in the future.

SOLAR ROTATION AND LIMB-CENTER DISPLACEMENTS

Measurements of the rotation of the sun are being continued by St. John, but are limited at present to the solar equator and to a region in the red portion of the spectrum in which atmospheric lines are available to serve as a check upon the results.

The displacements at definite points between the center and limb of the sun for a selected list of lines have been measured by E. F. Adams in a study of the residual limb-effect after the relativity correction has been applied. The relation of the variation of wave-length between center and limb to changes in contour and intensity is also being investigated.

INFRA-RED SOLAR SPECTRUM

The study of the infra-red spectrum has been continued by Babcock with apparatus and methods described in previous reports. The work involves the application of the highest practicable resolving power to a detailed examination of the easily accessible region to about $\lambda 9000$, and the use of instruments of moderate scale for the more remote part of the spectrum. One series of high-dispersion measurements has been completed with the 21-foot concave grating in Pasadena, while others with the 75-foot spectrograph of the 150-foot tower and the 30-foot of the Snow telescope are well advanced. Although the observations with high dispersion are incomplete, hundreds of faint lines hitherto unrecorded have been accurately measured with reference to standards determined with the interferometer in Pasadena. For many of the lines already known in this region, a definite increase of precision has been attained.

In the more difficult region beyond $\lambda 9000$ the stigmatic concave-grating spectrograph in Pasadena has been particularly useful; and an improved filter prepared through the cooperation of Dr. C. E. K. Mees, Director of the Eastman Laboratory, has given results of unusual interest. A photographic map of the solar spectrum to $\lambda 11,634$ has been prepared, and over 350 lines have been measured beyond $\lambda 9867$. The published results of the bolometer show in this same region only 96 lines, many of which are doubtful, while the accuracy of the new wave-lengths is fully 100 times that attained with the bolometer. Beyond $\lambda 11,000$ nearly all the lines measured on our photographs are components of the great water-vapor band, but between $\lambda 9800$ and $\lambda 11,000$ the lines are probably in large part of solar origin. There is little doubt that carbon in the atomic state is represented by an important multiplet near $\lambda 10,700$; and potassium, magnesium, calcium and some other light elements have interesting lines in this region. The remarkable appearance of the hydrogen lines which occur here indicates that significant results are to be expected from a study of their contours by the method of Unsöld. The long exposures required for this part of the spectrum preclude the ordinary tests for distinguishing solar from telluric lines; but observations on days of high and low humidity show which lines are to be ascribed to water vapor. These probably include the greater part of all the telluric lines.

The number of solar lines measured beyond $\lambda 7330$, where Rowland's Table ends, is now about 2500, with a few hundred telluric lines. The spectral range of the region now being studied is 4304 Å, almost the same as that of Rowland's Table which contains over 20,000 lines. It is probable that about 18,600 of Rowland's lines are of solar origin. This number is 7.5 times that of the solar lines thus far measured in the infra-red region of the same range of wave-length. The disparity is only apparent, however, since it is the frequency range, and not the wave-length interval, which is

of physical significance. For the infra-red region now photographed this is only one-fourth that of Rowland's Table; and other things being equal, about 5000 solar lines might be expected as against the 2500 observed. Many faint lines will doubtless be discovered here when higher photographic speed permits the use of more powerful instruments.

In the visible and ultra-violet regions an average of 24 per cent of the lines are of intensity -3 . In the green-red region, however, this percentage steadily increases with the wave-length to about 50 per cent at λ 6500. If this percentage is maintained in the adjoining infra-red it would account for the fact that only 2,500 lines have been observed where 5000 are to be expected, for the faintest infra-red lines measured are certainly stronger than -3 . For equal intervals of the wave-number scale the solar spectrum is therefore probably as rich in the infra-red as in the region of shorter wave-lengths.

Arc wave-lengths of greater accuracy are much needed for comparison with the new solar data in the infra-red. The difficulties are considerable, but preliminary spectrograms of cobalt, calcium, iron, potassium, and boron have been made in the near infra-red with low dispersion, preparatory to a more extended investigation.

THE ATMOSPHERIC ABSORPTION BANDS OF OXYGEN

Measurements of atmospheric oxygen bands by Dieke and Babcock three years ago, as noted in the Report for 1927-28, led Giauque and Johnston to the discovery of an isotope of oxygen of mass 18 and to much further study of these bands and the bands of some other light elements, in which a number of other observers are now concerned. From improved spectrograms Babcock was able to extend the analysis of the faint band which furnished the evidence for the existence of O^{18} and to discover two new bands, extremely weak, one of which is the second in sequence of bands arising from the molecule $O^{16} - O^{18}$, while the other has been interpreted by Giauque and Johnston as due to an isotope of mass 17. The intensities of all these isotopic bands are so low relative to those of the ordinary molecule, $O^{16} - O^{16}$, that direct comparison, either visually or by microphotometer, was of little use; but by photographing a strong ordinary band with a short air-path and a weak band with a very long air-path, they could be made to appear alike. This gave a reliable measurement of their true relative intensities, and hence of the relative abundance of the atoms O^{16} and O^{18} , which was found to be approximately 1250:1. The value of this ratio accounts for the non-appearance of O^{18} in the mass spectrograph. Estimates of the intensity of the band arising from $O^{16} - O^{17}$ indicate that there is only one atom of O^{17} to every 10,000 of O^{16} . O^{17} is therefore much scarcer than O^{18} .

The discovery of the atoms O^{18} and O^{17} illustrates the sensitivity of the spectroscopic method and suggests that many other elements may have undiscovered isotopes in small proportion. In fact the discovery of C^{13} by Birge and King from measurements of the band spectrum of carbon quickly followed the results for oxygen. Of even greater interest is the fact that the spectroscopic method can in some cases furnish an extremely accurate measurement of the relative atomic weights of isotopes. As pointed out by Giauque, we thus have a new approach to the study of the so-called packing

effect, which determines the amount of energy set free as high-frequency radiation when light atoms unite to form a heavy one whose mass is slightly less than the sum of its components. Measurements already made for oxygen indicate that it will be possible to obtain the relative masses of the atoms O^{16} and O^{18} with an accuracy of 1 part in 20,000. The problem is being studied jointly with Doctors Giaque, Johnston and Birge of the University of California.

SPECTROPHOTOMETRY OF SOLAR LINES

The publication of the *Revision of Rowland's Table of Solar Spectrum Wave-Lengths* by St. John, Miss Moore, Miss Ware, E. F. Adams and Babcock marks the end of the first stage in the production of a table in which it is hoped that the wave-lengths of all lines may be measured on the International system, and the intensities determined on a quantitative and absolute scale. Plans are now being considered for the measurement of the intensities of solar spectrum lines in great numbers with the aid of a powerful concave-grating spectrograph and a registering microphotometer. For immediate use in the theoretical investigation of solar problems, St. John is engaged upon a program involving the determination of the residual intensity, the half-width, and the contour of a selected list of lines which are related by the theory of spectra, such as components of multiplets, triplets, singlets, etc. For faint lines the total absorption rather than the contour must probably suffice. Comparison of results obtained from high-dispersion spectrograms taken in successive orders will fix the limiting intensity for which contours are trustworthy.

ULTRA-VIOLET SOLAR RADIATION

Five years of observations on the ultra-violet solar radiation at $\lambda 0.32\mu$ have been completed by Pettit. The general trend of the monthly averages follows the sun-spot frequency-curve, except for the summer of 1928 when a well-marked depression in the ultra-violet curve corresponded to a rise in sun-spot frequency. The highest monthly mean value of the intensity ratio $\lambda 0.32\mu$ to $\lambda 0.5\mu$ is 1.57, for November 1925; and the lowest, 1.12, for September 1928.

The transmissions of the silver and gold films on the quartz optical parts have been tested at intervals of one or two years and appear satisfactorily stable. A plot of atmospheric transmissions shows relatively small variations which appear to have no relation to the observed variations in ultra-violet light.

Records made in Pasadena with the photoelectric radiometer, which uses a silvered quartz photoelectric cell and gives the solar radiation plus sky radiation at $\lambda 0.32\mu$, show that in this wave-length the total energy incident on a horizontal surface during the day at the winter solstice is 20 per cent of that at the summer solstice. By the use of a Wratten 56B3 filter, combined with Corning Blue Purple Corex over a photoelectric cell, it was found that at $\lambda 0.30\mu$ the sky light is approximately equal to direct sun-light received on a horizontal plane.

With the 1-meter concave grating crossed with a quartz monochromator the ultra-violet limit of the sky-spectrum at an altitude of 57° above the

northern horizon was studied. With an exposure of 6 hours in July the limit was $\lambda 0.293\mu$, while 60 hours in December gave $\lambda 0.297\mu$. Used on sun-light reflected from a steel-mirror siderostat, the same apparatus, with the addition of a quartz objective and a quartz bromine filter combined with Blue Purple Corex, gave with an exposure of 2 hours wave-lengths slightly below $\lambda 0.29\mu$.

ULTRA-VIOLET ENERGY CURVE OF THE SUN

Preparations have been made by Pettit to determine the energy curve in the ultra-violet region of the solar spectrum. Two Bausch & Lomb quartz monochromators have been attached to a single mounting with a straight slit in common so that one acts as a filter for the other. A siderostat with steel mirror furnishes the sunlight. A thermocouple and a quartz photo-electric cell are both used in the measurements.

INTERPRETATION OF LINE CONTOURS

It has long been known that spectroheliograms taken in the center of a broad line correspond to the highest levels of the solar atmosphere, while those taken in light from the wings of a line represent lower layers. Dr. Unsöld has interpreted these facts on the theory of radiative equilibrium of the solar atmosphere. His formulæ give the intensity of the emergent light as a function of the temperature, and of the coefficients of scattering and absorption. He obtains a useful approximation to actual solar conditions by assuming that the reversing layer consists of two strata to which different constants may be assigned. On this hypothesis, the narrow K_2 portion of the calcium line arises in the tenuous chromosphere. Unsöld has suggested an explanation for the puzzling observation that lines in the same multiplet seem to indicate different velocities for the atoms which produce them.

It is obvious from spectroscopic observations that the solar atmosphere contains many atoms in excited states, that is, atoms which momentarily have more than their normal amount of energy, but it is difficult to determine the exact percentages in the various states. Dr. Unsöld's investigation of the subject indicates that for excitation potentials up to 1.7 volts the distribution corresponds, within the accuracy of measurement, to Boltzmann's formula. This is in harmony with the assumption by Adams and Russell that the deviations from this formula found in stellar atmospheres are due to an oversupply of atoms in the highly excited states rather than a lack of those in the low states.

Dr. Unsöld's determination of the number of atoms effective in producing the solar $Ca II$ lines leads to 10^{-2} sec. as the minimum value of the life of the $Ca II$ atom in the metastable 3D state.

THE COMPOSITION OF THE SUN'S ATMOSPHERE

Dr. Russell in an extensive investigation has applied modern physical and astrophysical developments to a rational explanation of the relative abundance of different elements in the solar atmosphere and the significance of the apparent absence of the lines of certain elements from the solar spectrum.

Starting from a consideration of the energy of binding of an electron in different quantum states by neutral and singly ionized atoms, Russell discusses the structure of the spectra of the various elements, their ionization potentials and most persistent lines. The presence or absence of the lines of a given element in the solar spectrum is seen to depend mainly upon the excitation potential for the strongest lines in the observable part of the spectrum. Nearly all the elements for which this excitation potential is low show lines in the solar spectrum, but very few lines are present for which it exceeds 5 volts. The only strong ones are those of hydrogen.

The abundance of the various elements has been calculated with the aid of the calibration of Rowland's scale and the work of Unsöld on certain important lines. The numbers of atoms in the more important energy-states are found to decrease with increasing excitation, but a little more slowly than is demanded by thermodynamic considerations. A computation based upon 5 elements for which the principal lines of both the neutral and the ionized atoms are accessible indicates that atoms in the solar atmosphere with an ionization potential of 8.3 volts are 50 per cent ionized. From tables of the relative abundance of 56 elements and 6 compounds it is shown that 6 elements—sodium, magnesium, silicon, potassium, calcium and iron—contribute 95 per cent of the whole mass. The whole number of metallic atoms above a square centimeter of the surface is 8×10^{20} . Eighty per cent of these are ionized. Their mean atomic weight is 32 and their total mass 42 mg./cm². The elements of even atomic number are, on the average, 10 times as abundant as those of odd number. The heavy metals, from barium onward in the periodic table, are but little less abundant than those following strontium, and the metals from sodium to zinc, inclusive, are far more common than the others. The compounds are present in but small amounts. Most of the elements which do not show lines in the solar spectrum would not be expected to do so unless their abundance were much greater than is at all probable, but there is a possibility of finding faint lines of some additional rare earths and heavy metals, and perhaps of boron and phosphorus.

It is difficult to estimate the abundance of the non-metals from the few lines available, but oxygen appears to be about as abundant by weight as all the metals together. A final estimate is that the solar atmosphere contains 60 parts of hydrogen (by volume), 2 of helium, 2 of oxygen, 1 of metallic vapors and 0.8 of free electrons, nearly all of which come from ionization of the metals. The great abundance of hydrogen helps to explain a number of previously puzzling astrophysical facts. The temperature of the sun's reversing layer is estimated at 5600° C., and the pressure at its base at 0.005 atmosphere.

IDENTIFICATION OF BORON IN THE SUN

Several of the band lines of boron compounds were identified by Nicholson and Perrakis with faint lines in the spectra of sun-spots, thus establishing the presence of that element in the sun.

LUNAR OBSERVATIONS

Direct photographic observations of the moon have included numerous photographs made by Pease through various color filters, and six negatives of the earth-lit moon obtained by Dr. Duncan with the 100-inch reflector for the use of Professor W. H. Pickering.

Drawings of certain features of the moon's surface have been made on various occasions by Mr. R. W. Porter, and visual observations have been carried on by Professor Pickering, and Dr. Wright, Dr. Buwalda, and other members of the Committee on the Study of the Surface Features of the Moon.

LUNAR RADIATION

A reduction of the measurements of lunar radiation made with the 100-inch telescope since 1922 has been completed by Pettit and Nicholson. Drift curves across the disk at full moon, with and without glass screen, give the distribution of planetary heat and reflected light. These show that the distribution of heat follows the law $E = a \cos^3 \theta/2$, where θ is the angular distance from the sub-solar point, whereas the theoretical distribution over the illuminated hemisphere is given by $E = a \cos \theta$. This difference may be explained by the rough surface of the moon. In general, the distribution of reflected light follows Lambert's cosine law, although the maria are only three-fourths as bright as the mountainous regions in the middle of the disk.

The radiometric magnitude of planetary heat from the sub-solar point at full moon is $+1.39$ per square second of arc, corresponding to a temperature of 402°K , while at quarter phase it is $+1.92$, corresponding to 355°K . The rough surface thus seems to have a directional effect on the radiated planetary heat. The reciprocity principle indicates that it is the average energy vector of the emitted radiation which is to be compared with that received from the sun. The complete distribution function is being determined by measurements at various phases; but, on the assumption that this function is elliptical, the mean radiometric magnitude of planetary heat at the sub-solar point is $+1.74$ per square second of arc, corresponding to 370°K .

The total reflected light determined with the cover-glass and water-cell at full moon and at quarter phase is $0.36 \text{ cal. cm.}^{-2} \text{ min.}^{-1}$; the conducted heat as found at the eclipse of June 14, 1927, is $0.1 \text{ cal. cm.}^{-2} \text{ min.}^{-1}$. With a value of $1.95 \text{ cal. cm.}^{-2} \text{ min.}^{-1}$ for the solar constant, these data give a temperature of 367°K for the sub-solar point and a radiometric magnitude of $+1.76$ for the planetary heat, in good agreement with the radiometric measurements.

Measurements made on a point 0.05 radius from the south limb at the lunar eclipse of June 14, 1927, show that, if restoration of the stable state required the supply of as much heat as was given up by the moon during the eclipse, the amount received at the beginning of the eclipse must have been about $0.1 \text{ cal. cm.}^{-2} \text{ min.}^{-1}$.

From the data obtained at this eclipse, Epstein has shown that $(k\rho c)^{-1/2}$ is about 120, corresponding to volcanic ash or pumice. For granite, basalt, sandstone and other common rocks the value is much less than this.

The radiometric magnitude of the total reflected light from the full moon is -13.1 , and of the total radiation -14.6 . The radiometric albedo of the moon is 0.078 ; for visual light the albedo is 0.073 .

The radiometric magnitude per square second of arc of planetary heat reaching us from celestial objects of various temperatures indicates that the lowest temperature which can be detected with certainty is about 70° K and that temperatures below 100° K can be measured only with great difficulty.

LUNAR RADIATION DURING AN ECLIPSE

Radiation from the moon during the lunar eclipse of November 26, 1928, was examined by Pettit with a special equipment adapted to the Snow telescope. A 27-inch mirror of 67 inches focal length was used. An automatic device registered at intervals of 20 seconds the total radiation and that transmitted by the cover-glass screen, and printed a time scale on the plate. Radiation from the center of the disk was measured throughout the eclipse. The results agree substantially with those obtained from a point 0.05 radius from the south limb at the eclipse of June 14, 1927, but are more detailed. The same equipment is being used to determine the distribution of planetary heat and reflected light over the hemisphere about the sub-solar point.

RESEARCHES ON NEBULÆ

Aside from the photographs required for the investigations summarized below, a good plate of the Veil nebula, N.G.C. 6992, was obtained by Dr. Duncan with an exposure of $6^h 30^m$ at the 100-inch telescope. Duncan also discovered 4 novæ on a plate of the Andromeda nebula taken on July 16, 1928, the largest number thus far found on any single plate.

Photographs were made by Pease with the 100-inch reflector of the Dumbbell nebula and N.G.C. 6888, a filamentary nebula near N.G.C. 6992, and were compared with negatives taken many years previously. In neither case was any change found in the nebulosity; but two variable stars or novæ were discovered in the Dumbbell nebula, distant $2'5$ and $3'5$, respectively, from its center. Similarly in the case of N.G.C. 6888, a variable star or nova was found on a plate taken on July 10, 1928, which did not appear on a plate taken on July 16, 1928. The star is $20''$ south of B.D. $+38^{\circ}3946$.

INVESTIGATION OF STARS INVOLVED IN EXTRA-GALACTIC NEBULÆ

Contribution No. 376, published by Hubble during the year, completes the investigation of the three extra-galactic systems observable from the Northern hemisphere in which individual stars can be studied in detail. Attention is now concentrated on a selected list of spirals and irregular nebulae which, although fainter and more distant, still show considerable numbers of stars among which to search for criteria of absolute magnitude. These criteria are the sole basis for determining nebular distances and are essential for the calibration of all indirect methods of measuring such distances. An effort is also being made to determine the distance of the Virgo cluster, the nearest of the great clusters of nebulae, from stars involved in individual spirals. With reliable distances thus available for several

hundred nebulae of different types, statistical methods can probably be established for the study of more distant clusters and for nebulae in general.

VELOCITY-DISTANCE RELATION AMONG EXTRA-GALACTIC NEBULAE

Criteria of distance based on the stars involved in nebulae, even in their present approximation, have been successfully used by Hubble to establish an apparently linear relation between the distances and radial velocities of extra-galactic nebulae. The velocity apparently increases about 500 km./sec. for each 1,000,000 parsecs of distance. This relation eliminates the large K term involved in the older determinations of the sun's motion relative to the nebulae, and indicates for the nebulae in general an average peculiar radial velocity of the order of 150 km./sec.

For the nebulae for which velocities but no individual distances are available, the correlation furnishes distances which are consistent with the absolute magnitudes and the luminosity function of nebulae. Moreover, the velocities of several very faint nebulae recently determined by Humason and Pease tend to confirm the general nature of the velocity-distance relation. Further confirmation is highly desirable, but it already seems probable that the relation will ultimately furnish a method of determining individual distances for which the relative accuracy increases with the distance.

NEBULAR SPECTROSCOPY

Spectroscopic observations of some of the more distant extra-galactic nebulae have been started by Humason and Pease during the year. These faint objects are being observed to test the velocity-distance relation found by Hubble to hold for the nearer nebulae, and to determine whether this correlation can be explained by de Sitter's theory, according to which displacements of spectral lines may arise partly from an apparent slowing down of atomic processes and partly from a general tendency of material particles to scatter.

The objects selected as being most distant, and for which spectrograms can be obtained with the present instrumental equipment, are the brighter nebulae occurring in clusters of nebulae. The following have been observed during the year: N.G.C. 4853 by Pease; N.G.C. 4860 by Pease and Humason; and N.G.C. 4865 and 7619 by Humason. The first three are in the Coma Berenices cluster near the pole of the Milky Way; N.G.C. 7619 is one of the brighter nebulae in the cluster at R.A. 23^h 16^m, Dec. +7° 50'. Expressed as radial velocities, the displacements are:

N.G.C. 4853	+7300 ± 250 km./sec.
4860	+7800 ± 250
4865	+4700 ± 250
7619	+3800 ± 100

The following extra-galactic nebulae, which are not members of any cluster, have been observed by Humason:

N.G.C. 3227	+1150 ± 200 km./sec.
4051	+ 650 ± 50
6359	+2800 ± 250

The spectral displacements found for these nebulae, as for practically all extra-galactic nebulae which have been spectroscopically observed, are systematically to the red and of such an amount as to raise a question as to whether they represent the actual radial velocities of the nebulae.

The observations were made with Cassegrain spectrograph VI, used with either one or two prisms. The larger probable errors indicate the nebulae observed with the smaller dispersion. The H and K lines of calcium are measurable on the low-dispersion spectrograms; the exposure times ranged from 20 to 50 hours according to the brightness of the nebulae.

DISTANCE OF THE COMA CLUSTER OF NEBULAE

A provisional estimate by Hubble of the distance of the Coma cluster of nebulae (R.A. $12^h 56^m$, Dec. $+28^\circ 25'$) indicates a value of the order of 50,000,000 light years. The estimate is based upon a comparison of the mean apparent magnitude of the cluster nebulae (15.8 photovisual) with the previously determined mean absolute magnitude of nebulae in general (-15.2). Both photovisual magnitudes are provisional, the latter because of the limited data available, the former because of inherent uncertainties in the photometry of elliptical nebulae, the dominating type in the Coma cluster, as in almost all of the other known clusters.

Among elliptical nebulae, diameters, and hence total luminosities, have been found to vary with exposure time and at a rate depending on the central luminosity and other factors. An investigation based on extra-focal exposures with various instruments is under way for the purpose of determining corrections which will reduce measures made under different conditions to a uniform system.

GENERAL SURVEY OF SMALL NEBULAE

The systematic survey of small nebulae by Hubble mentioned in the previous report is about 90 per cent complete. When finished, the material will consist of about 500 plates of an hour's exposure each, made indiscriminately with the 60-inch and 100-inch reflectors and uniformly distributed over the sky from the pole to declination -25° ; 360 fields were completed during the last year. These photographs will supplement the several hundred already available which are not uniformly distributed but centered upon particular nebulae. The general purpose is the investigation of the influence of galactic latitude, and especially of the Milky Way itself, on the distribution of nebulae, and a more reliable determination of the density function.

PROPER MOTION OF THE SPIRAL N.G.C. 4051

From 5 pairs of exposures made at the 80-foot focus of the 60-inch reflector with an interval of 11 years, van Maanen finds the relative motion of the spiral nebula N.G.C. 4051 to be $+0''.005 \pm 0''.001$ in right ascension and $+0''.017 \pm 0''.0015$ in declination. The images of the stellar nucleus are practically as good as those of the comparison stars. It is improbable that the displacement has been caused by a magnitude error or by quadratic terms. The reduction to absolute motion is subject to the uncertainty of the parallax motion of the comparison stars, but this correction does not influence the r -component of the motion, which is $0''.014 \pm 0''.0015$. On the

assumption that the motion is comparable with the radial velocity of 650 km./sec., the parallax would be about $0''.000065$. This would give -2.9 for the absolute magnitude of the central condensation. The spectrum, according to Humason, is of the planetary-nebula type. Stars showing spectra of this type have absolute magnitudes in good agreement with that suggested for the nucleus of N.G.C. 4051. On account of the importance of the result, more data will be obtained as soon as possible.

MISCELLANEOUS STELLAR INVESTIGATIONS

TRIGONOMETRIC PARALLAXES

Van Maanen has continued the measurement of trigonometric parallaxes, obtaining 80 plates with 146 exposures at the primary focus of the 100-inch reflector, and 107 plates with 198 exposures at the Cassegrain focus of the 60-inch reflector. Parallaxes were derived for 17 fields.

The largest parallax, $+0''.213 \pm 0''.023$, was found for Wolf 562, which has an annual proper motion of $1''.33$. The value derived for Nova Lyræ 1919, π abs. = $+0''.016 \pm 0''.007$, gives absolute magnitudes of $+2.5$ for maximum and $+12.0$ for minimum light. For Ross 136, the first star from the several lists of faint stars with large proper motion discovered by Ross for which a parallax has been derived here, the result is $+0''.084 \pm 0''.006$. This corresponds to absolute photographic magnitude $+14.2$. Another interesting object is the faint double star $12''.6$ west and $1''.6$ north of Messier 15, which was discovered in 1925 by Humason as having a large proper motion. The annual proper motion is $0''.499$, the absolute parallax $+0''.033 \pm 0''.007$. The photographic absolute magnitudes of the components, which are separated by only $1''.13$, are $+8.7$ and $+11.8$.

In measuring the plates for N.G.C. 246, one of the largest known planetary nebulae, it was found that a faint star $4''$ distant from the central star and the central star itself have practically the same proper motion, *viz.*, $0''.043$ per year. Probably the two stars form a physical system. If so, the fact is of extreme interest since the companion has a color-index corresponding to a G5-K spectrum. It is hoped that it may be possible to photograph the spectrum of the companion, as this would afford an independent determination of the absolute magnitude.

PROPER MOTIONS

Van Maanen obtained 23 plates with 32 exposures and 74 plates with 96 exposures at the 100-inch and 60-inch reflectors, respectively, for the measurement of proper motions. Most of these are first-epoch plates for the fields of Cepheid variables. First-epoch plates are now available for 113 fields.

Proper motions have been derived for 5 planetary nebulae from 2 pairs of exposures taken at the 80-foot focus of the 60-inch reflector with intervals ranging from 9 to 13 years. The preliminary results are:

	μ_{α}	μ_{δ}	μ
N.G.C. 6058	$+0''.002$	-0.010	$0''.010$
6210	$+0.003$	-0.011	0.011
6543	$+0.002$	-0.002	0.003
6572	-0.002	$+0.002$	0.003
6720	$+0.005$	$+0.006$	0.008

These proper motions are relative to the comparison stars and are so small as to suggest that these planetaries can not be much nearer to us than the comparison stars, which are of magnitude 11.5 to 13.5.

During the years 1909-1912 Selected Areas 1-115 were photographed by Babcock and Fath at the Newtonian focus of the 60-inch reflector with exposures of 60 minutes and 5 minutes. The plates, which are a part of the data for the *Mount Wilson Catalogue of Photographic Magnitudes*, are being utilized as first-epoch photographs for a study of the proper motions of faint stars. During the year several of the fields have been photographed again by Duncan, Hoge and Christie. The old and new plates for 21 fields have been compared by van Maanen with the blink arrangement of the stereocomparator. It is estimated that about 34,000 stars having magnitudes from 10 to about 20 were investigated. Fifty-nine stars were found to have considerable proper motion, ranging from $0''.049$ to $0''.451$ annually. A preliminary discussion of the material leads to the following conclusions: (a) In the mean the proper motions are smaller for the fainter stars. (b) The percentage of proper-motion stars increases with increasing galactic latitude. (c) The size of the proper motion increases considerably with galactic latitude. (d) The provisional value of the apex for stars fainter than magnitude 17 coincides closely with the main apex in R.A. $18^h 40^m$, Dec. $+30^\circ$.

STELLAR PHOTOMETRY

The catalogue giving the photographic magnitudes of 67,941 stars in Selected Areas 1-139 is in press. Proofs have been read for the 50 pages of introduction and for 100 of the 273 pages of the catalogue itself.

The reduction of the observations for photovisual magnitudes in 42 Selected Areas, by Seares and Miss Joyner, is now actively under way. The observations were completed in 1921, but the measurement and reductions have been carried on in the past only as the demands of other work permitted. The fields include 6 Areas at intervals of approximately 4 hours in right ascension in each of the declination zones from $+75^\circ$ to -15° . The scale is determined independently for each Area by diaphragm exposures and by photographs of long and short exposure on the same plate. Comparisons of each field with the pole and with the adjacent Areas in the same declination provide data for reduction of the magnitudes to the international zero point. The zero-point differences are subject to closing conditions as in a triangulation net, which affords a valuable check on the reductions.

The comparison photographs, which show stars down to about the fourteenth magnitude, are also being used to strengthen the scale determinations by transferring the scale from field to field. To the fourteenth magnitude the adopted scale for any Area is the mean of that at the pole and of the scales independently derived for the Area in question and for the preceding and following Areas in the same zone of declination. Beyond this point the magnitudes are based on two photographs of each Area having exposures of 60 minutes and 5 minutes on the same plate. The limiting magnitude thus reached is 15.5 or 16 photovisual.

The reductions are complete for the zone at $+45^\circ$. The total number of stars observed in the 6 fields ($23'$ in diameter) is about 2400; but, owing to

differences in limiting magnitude for the long-exposure plates, many of the faintest stars appear on only a single plate. Exposure-ratio photographs for the determination of color-index are also available for this zone. As far as the reductions are complete, the color-indices thus found are generally in good agreement with those obtained from the magnitudes of the stars.

STELLAR INTERFEROMETERS

Observations with the 20-foot interferometer have been continued by Pease, but during the short periods available for this work the seeing conditions have rarely been equal to the exacting requirements. This has been true especially during the winter months, and for this reason the measurements of the diameter of Betelgeuse have been unsatisfactory. Observations of α Ceti (Mira) at the maximum of 1928 showed disappearance of the fringes at a mirror-separation of 10 feet, indicating a diameter of $0''.047$. The previous value was $0''.056$.

Much progress has been made during the year toward the completion of the 50-foot interferometer, and it is hoped to secure observations with the instrument during the autumn months. The optical parts have been finished, and the mechanical parts, with the exception of portions of the mirror adjustments, are complete. The difficult work of the alignment of the accurately surfaced tracks upon which the outer plane mirrors are moved in and out is now in progress. The slow-motion control in right ascension has been assembled and installed, and the electrical wiring of the telescope and building has been completed by our engineers, Dowd and Sidney Jones.

STELLAR SPECTROSCOPY

The large spectrograph at the coudé focus of the 100-inch reflector has been used in a variety of forms during the year and much experimental work has been carried on with a view to adapting it to various problems. The instrument may now be used in the auto-collimating form with focal lengths of either 9 or 15 feet, and with either a dense flint glass or a light crown prism transparent to the ultra-violet. It is also possible to adapt the spectrograph for use with a single prism and cameras of short focal length. Methods have been developed for standardizing the high-dispersion spectrograms to make them available for measurements of the contours and intensities of the spectral lines.

A new camera lens of 18 inches focal length, constructed according to the design of Dr. Ross, has been added to the equipment of the Cassegrain spectrograph of the 60-inch reflector. When used in conjunction with a new telephoto collimating lens by Bausch and Lomb, this camera has given a great improvement in the quality of the spectrograms, the field of good definition extending from H and K to the region of $H\alpha$. It will be especially useful in the case of stars of spectral types A and B.

A new quartz spectrograph of small size for use at the primary focus of the two reflectors has been completed recently, and work is well advanced on an additional short-focus instrument similar in type to that which has proved so successful in observations of faint stars and nebulae at the Cassegrain focus of both telescopes.

The spectroscopic observations have been carried on by Adams, Dunham, Humason, Joy, Merrill, Sanford and Strömberg of the regular staff. Dr. Duncan and Dr. Leonard have made investigations of the spectra of certain spectroscopic binaries and the fainter components of visual double stars. During the year, 1131 spectrograms have been obtained with the regular one-prism Cassegrain spectrographs, 366 with the 100-inch, and 765 with the 60-inch reflector. In addition, 104 spectrograms of faint stars and nebulae have been made with the small Cassegrain instrument and 71 spectrograms, mainly of bright stars, with the 15-foot and 9-foot coude spectrographs. The spectra of a considerable number of stars in the red region of the spectrum have been photographed with the plane-grating spectrograph.

RADIAL VELOCITIES

The radial velocities of about 75 stars of constant velocity have been determined from measurements of three or more spectrograms. A catalogue of the radial velocities of 741 stars has been compiled from the observations of recent years by Adams, Joy, Sanford and Strömberg. The visual magnitudes range from 3.0 to 10.8, the list containing a considerable number of faint stars of large proper motion. A previous comparison with the values for the brighter stars obtained at the Lick Observatory, mainly with a dispersion of three prisms, had shown the existence of small systematic differences in the case of the stars of the later spectral types which seemed to be due mainly to the wave-lengths used for some of the blended lines. Accordingly the following corrections were applied to the Mount Wilson velocities: Type F, +0.5; G, 0.0; K, -0.9; M, -0.8 km./sec. With these corrections applied, the stars observed in common with the Lick and Dominion Astrophysical Observatories provide the following comparison:

Type	No.	Mt. W.—Lick	Type	No.	Mt. W.— Dominion
B	15	+1.2 km./sec.	B	..	....
A	20	-0.7	A	8	-0.6 km./sec.
F	12	+0.7	F	17	+1.6
G	28	-0.7	G	30	+0.3
K	36	+0.5	K	26	+1.1
M	31	+0.1	M	15	+0.8

The catalogue contains 26 stars with radial velocities exceeding 70 km./sec., when corrected for the solar motion, and 7 stars with velocities exceeding 100 km./sec. About 60 stars have velocities exceeding 50 km./sec. These rapidly moving stars show in a very marked way the asymmetry of stellar motions investigated by Strömberg, the consequence being an almost complete absence of stars of large positive velocity in the northern sky between 15 and 24 hours of right ascension.

Among other results of interest are the addition of six stars to the Taurus group through measurements of their radial velocities, and the evidence that the distant tenth magnitude companion of Capella shares in the motion of the bright star.

The velocity-curves of several spectroscopic binaries have been under investigation by Sanford, and sufficient material has been obtained to determine the orbits of Lalande 17480 and Boss 4865. About 50 spectrograms of Boss 1216 have been secured and the results will be used by Mr. S. N.

Hill, of the Dominion Astrophysical Observatory, who has also been observing this star. The values found at the two observatories are in satisfactory agreement. The velocity-curve of the Cepheid variable W Geminorum with a period of 7.9 days has been determined by Sanford, and measures of high-dispersion spectrograms of α Orionis complete a series extending over approximately the full 6-year period assigned to this star by some observers.

Measurements of the radial velocities of N-type stars by Sanford, of Cepheid and short-period variables and those of the RV Tauri type by Joy, of certain long-period variables by Merrill, and of stars in the Selected Areas by Humason, have been continued throughout the year.

SPECTRA OF VARIABLE STARS

Spectroscopic observations of a large number of variable stars have been made by Joy. The list includes 76 regular Cepheids, 47 short-period variables of the RR Lyræ type, 29 stars with periods between 50 and 130 days, mostly of the RV Tauri type, and 24 eclipsing variables. The spectra have been studied critically for variations of light with phase, and have also been measured for radial velocity. Results for W Serpentis, W Virginis, U Sagittæ, RS Canum Venaticorum and RT Lacertæ are nearly ready for publication. The peculiar velocity changes of the eclipsing star SX Cassiopeïæ have been followed, but so far no plausible explanation for its behavior has been found. Numerous spectrograms of the Cepheid Y Sagittarii have been obtained at the request of Dr. ten Bruggencate who is studying the relationship of its spectrum and radial velocity to its photometric changes.

The faint companions of the Cepheid variables Y Lacertæ and RY Scorpii and of the eclipsing stars SX Cassiopeïæ and X Trianguli are being observed spectroscopically with low dispersion.

LONG-PERIOD VARIABLES

A comparative study of the intensities and displacements of the bright lines in the spectra of long-period variables has been nearly completed by Merrill. The data include several measurements of the bright $H\alpha$ line.

A special investigation of R Virginis, period 145.4 days, has been finished by Merrill and Joy. The light range, 4.5 magnitudes, is unusually large for a star with so short a period. The spectral type is M4e at maximum and M8 near minimum. The spectroscopic absolute magnitude at maximum is -0.6 . The curve of velocities derived from the absorption lines resembles the light-curve, but that from the bright hydrogen lines is entirely different. The velocity from the bright lines varies from -25 km./sec. 40 days before maximum, to -40 km./sec. 20 days after maximum. An observation of small weight indicates the return to a velocity of -25 km./sec. 60 days after maximum. The bright hydrogen lines have their greatest intensity near maximum of light; their displacements behave in the same general manner as in α Ceti, but there are interesting differences between the two stars. The low-temperature lines of iron, magnesium and other elements, observed in emission in α Ceti, are weak or absent from R Virginis.

B-TYPE STARS WITH EMISSION LINES

Observations of stars of type Be by Merrill, Humason and Miss Burwell have been continued throughout the year, and several new spectra of this

type have been discovered. Numerous stars of special interest are under investigation.

A detailed study of the complex spectrum of B.D. +11°4673 and its curious behavior since 1915 has just been completed. More than 160 bright lines have been observed, of which nearly all are variable in intensity and position, and some in structure. The most conspicuous features of the spectrum are the bright hydrogen lines, which vary in intensity but are always strong. The helium lines have behaved in a striking manner. In 1915 they were dark; in 1919, nearly neutral; in 1920 they were emerging in emission; and since June 1921 they have been present on all the spectrograms as strong bright lines, accompanied by dark borders of shorter wavelength. Numerous well-known iron spark lines are conspicuous; they appear in emission on many spectrograms, but on others of equal quality are scarcely visible. Forbidden lines of the ionized iron atom, recently identified in the spectrum of η Carinæ, are present in emission on many plates. Other elements, represented chiefly by emission lines, with their respective degrees of ionization, are as follows: *Al* II, III; *N* II, including the forbidden (nebular) lines $\lambda\lambda$ 5755, 6548, 6583; *Si* I (?), II, III, IV; *Ti* II; *Cr* II; *Mg* II. The variations in the intensities of the bright lines are rather gradual. Plates taken within a few weeks do not exhibit a wide range of behavior, but from one year to another large differences may appear. A notable phenomenon, beginning in 1920, was the simultaneous strengthening of the hydrogen, helium and enhanced iron lines. A strict periodicity in the various changes is lacking, but the recurrence of certain features at intervals of about 800 days is noticeable. The variation in the position of the lines differs for the various elements in an extraordinary fashion. The 800-day cycle is a common feature, but the amplitudes, phases and mean velocities differ by surprisingly large quantities. The facts suggest a star with an extensive, tenuous atmosphere in which the chemical elements are well sorted by light pressure and gravitation.

MISCELLANEOUS

The classification of the spectral types of the faint stars in the Selected Areas has been continued by Humason who has now completed 89 of the 115 areas under investigation. Dr. Leonard has added to his results on the classification of the faint components of visual binaries, giving especial attention to the companions of dwarf stars.

Additional investigations have included observations of stellar spectra in the region λ 7000– λ 8500 by Merrill; measurements of high-dispersion spectrograms of bright stars, with especial reference to the values from individual lines, by Adams and Christie; further studies of the spectrum of α Persei by Dunham; observations of the detached lines of *Ca* II and *Na* I in the spectra of early type stars by Merrill; and determinations of the radial velocities of β Cephei and δ Aquilæ by Dr. Duncan and his assistants.

An interesting observation was made by Pease with the low-dispersion spectrograph of the star Küstner 648 in the globular star cluster Messier 15. This star was found on direct photographs to be exceptionally bright in ultra-violet light, and its spectrum proved to be that of a planetary nebula. The radial velocity is of the same order as that of the cluster.

STELLAR SPECTROPHOTOMETRY

A method of spectrophotometry applicable to photographs taken with the coudé spectrograph is being developed by Dunham. Uniform illumination of the slit has been provided from an artificial source in order that standardizing spectra may be photographed on each stellar plate by the use of a wedge close to the slit. Several types of wedge have been constructed, but the most satisfactory results have been obtained with a step-wedge consisting of twelve narrow sections of developed photograph film of increasing opacity, placed slightly out of focus. A method for calibrating such a wedge has been devised. The influence of the Eberhard effect and of the finite resolving power of the spectrograph on the observed contour of a stellar absorption line is being investigated.

ENERGY SPECTRA OF STARS

In continuation of his work on measurements of the spectral energy of stars with the radiometer made 5 years ago, Dr. Abbot undertook observations on Mount Wilson with the 100-inch telescope during August and September 1928. He used for the purpose a special radiometer, designed by himself, with vanes made of flies' wings suspended by a very fine quartz fiber in an atmosphere of hydrogen at a pressure of 0.23 mm. The tube enclosing the radiometer was of fused quartz, optically figured, and could be rotated so that the light from the suspended mirror would pass out through the window in the brass case without the necessity of rotating the quartz suspension.

The period of swing of the vane system proved to be unexpectedly short, and consequently the instrument was less sensitive than had been hoped. During the period of use the time of a single swing averaged 1.5 seconds.

The observations were made in the constant temperature room at the coudé focus of the 100-inch reflector, the optical arrangement of the apparatus remaining much the same as it was for the earlier work. Two planets, Mars and Jupiter, were observed, and 18 stars, including representatives of all spectral types between B and M. The faintest star measured was δ Sagittæ of visual magnitude 3.8.

The results, when corrected for the selective absorption of the apparatus and the earth's atmosphere, have been shown graphically by Dr. Abbot in a series of interesting curves. A comparison with the values obtained in 1923 shows as good a degree of accordance as could be expected from the accuracy of the measures. The average probable error is about 10 per cent of the average deflection measured.

DETERMINATIONS OF LUMINOSITY AND PARALLAX

The classification of the stellar spectra obtained with the various instruments has been continued regularly, and estimates of the relative intensities of the lines used in the derivation of absolute magnitudes have formed a most important part of the work. The spectra of about 4000 stars have been investigated in this way since the method was first developed. The use of lines additional to those employed in the earlier work has made it desirable, however, to include values derived from these lines for all stars, in order that all of the absolute magnitude results may be strictly homogeneous. The estimates of the relative intensities of these additional lines

in the spectra of stars observed several years ago is well advanced and should be completed within a few months.

Among the stars in the *Preliminary General Catalogue* of Boss especial attention has been given during the year to those of types K and G0 according to the Draper classification. The values derived for the K-type stars are being used by Strömberg as the basis of an investigation of the luminosity distribution similar to that which he has completed for the M-type stars. The spectra of the G0 stars are being examined in a search for additional giants similar to the brighter component of Capella. It is known that stars of this type, with the exception of such as show the spectral characteristics of Cepheids, are few in number, and a list complete to a definite limiting visual magnitude would be of considerable value.

A special study of the spectra of 80 Cepheid variables with periods between 1.6 and 45.2 days has been made in a provisional attempt to derive their absolute magnitudes by the spectroscopic method. The spectral types have been determined by comparison with a selected sequence of typical Cepheid spectra chosen to conform as closely as possible to the Draper system. Since the spectrograms were obtained at selected phases of light variation, the resulting estimates of spectral type represent mean values for the stars. Small corrections have been applied when necessary.

For a first approximation the absolute magnitudes were derived by simple extrapolation from the reduction curves for ordinary giant stars. This is necessary since the intensities of the lines used, in all cases lines of ionized elements, fall beyond the limits found in the spectra of normal giants. The absolute magnitudes obtained in this way have then been compared with the values given by trigonometric parallaxes and by the period-luminosity relationship as derived by Shapley.

Trigonometric parallaxes measured by modern photographic methods are available for sixteen of the stars. They include 32 separate determinations, and with equal weights they give for the group a mean absolute magnitude of -1.6 . The mean of the spectroscopic absolute magnitudes for the same 16 stars is -1.7 . On the basis of existing trigonometric parallaxes, accordingly, no systematic correction to the provisional spectroscopic system is required.

A comparison of the spectroscopic values with those given by the period-luminosity relationship leads to quite other results. The mean for 63 stars is 0.99 magnitude fainter than the mean value of Shapley for the same stars. The differences are systematic, and evidently are due in the main to the standard reference points of the two systems. The period-luminosity relationship, however, gives relatively brighter absolute magnitudes for Cepheids of very short and very long period. The work now in progress at several observatories on the measurement of proper motions and radial velocities for these stars should go far toward fixing the reference points of the reduction scale.

The correlation between spectral type and the spectroscopic absolute magnitudes of these stars has been found to be extremely good, the relationship being very closely linear. If the standard reference points could be established independently, this curve would provide good values of the absolute magnitudes of Cepheids from the spectral types alone.

LUMINOSITY DISTRIBUTION OF M-TYPE STARS

A study has been made by Strömberg of different statistical methods for deriving the luminosity distribution among stars of known proper motion and radial velocity. The method first developed was that of computing the mean absolute magnitude and the dispersion from the absolute moments of first and second order of the r -components and the radial velocities. Applied to the giant M-type stars, this method gave the mean error in the spectroscopic absolute magnitudes, and the dispersion in the true absolute magnitudes for stars in low and high galactic latitude.

A more elaborate method was then devised by which the absolute magnitude distribution itself can be computed without making any assumption as to the analytical form of the distribution function. This method was also applied to the giant M stars, with the rather unexpected result that the luminosity function shows two distinct maxima, indicating the existence of two groups of stars clearly separated from one another, one of absolute magnitude about -2 , and the other of absolute magnitude 0 . The former group may be identified with super-giant M stars previously found by applying spectroscopic criteria; but the dispersion is less and the relative number of stars is greater than was anticipated. The other group has a somewhat larger spread in absolute magnitude than is indicated by the spectroscopic determinations.

The existence of two distinct groups of giant M stars might have been suspected from the fact that the apparently bright M-type stars in low galactic latitudes have a considerably higher intrinsic brightness than those of the same apparent brightness in higher galactic latitudes. The unusually large mean error in the spectroscopic absolute magnitudes for these stars has made it difficult, however, to study their true absolute magnitude distribution.

LABORATORY INVESTIGATIONS

SPECTRA OF THE RARE-EARTHS

The study of rare-earth spectra has been continued by King. The electric furnace, which has proved remarkably effective in producing the spectrum of the neutral atom for these substances, was used at various temperature stages for the regular temperature classification. The comparison of furnace, arc and spark spectra served to distinguish between neutral and ionized lines, difficult cases being decided by using a mixture with a substance of low ionization potential which suppresses the ionized lines in the furnace. The data for neodymium and samarium, extending from λ 2500 to λ 7000, are being treated in this way. For neodymium approximately 800 lines between λ 2950 and λ 4500 were measured in the furnace spectrum with reference to iron standards. Owing to their faintness in other sources, a large proportion of these lines was previously unidentified.

An examination of the region λ 3850 to λ 4700, important in astrophysics, was made of the furnace, arc and spark spectra of europium, gadolinium, terbium, dysprosium and holmium. On account of the extreme scarcity of these elements, our knowledge of their spectra is very limited. While the study is incomplete, extensive data for the more distinctive lines, especially those of the low-temperature furnace, have been tabulated.

Europium is peculiar in having a few very strong low-level lines in both neutral and ionized spectra, the remainder arising from much higher levels. Complex structure of individual lines is quite general. Gadolinium has a good distribution of sharp, low-temperature lines of stable wave-length, and is probably the most favorable of the rare earths as a source of wave-length standards. The terbium spectrum is very rich in lines, and the selection of neutral lines by the furnace is especially useful. Hyperfine structure is found in the case of many of the ionized lines of this element. For dysprosium, the furnace shows the presence of many strong low-temperature lines. Four of the strongest of these may be present in the solar spectrum, which would indicate an exception to the general condition of complete ionization of rare earths in the sun. Holmium is notable for the hyperfine structure of many lines, both neutral and ionized. Of the ten rare earths thus far studied by King, those of odd atomic number, beginning with lanthanum, have been found to possess hyperfine structure, while the lines of the alternate elements are sharp. A fundamental peculiarity based on the odd number of electrons is thus indicated.

THE SPECTRUM OF HAFNIUM

Hafnium, a metal discovered in 1923 and still very difficult to obtain in the purified state, was used by King in the furnace, arc and spark. A temperature classification of 338 of the stronger lines between λ 2650 and λ 6500 and the selection of ionized lines have been based on the data from the three sources. A system of bands appearing in the arc spectrum was found to be absent from the spectrum of the vacuum furnace, which indicates that they belong to the oxide.

SPECTRA OF OTHER ELEMENTS

The spectra of beryllium, boron, arsenic and tin were photographed by King in connection with questions as to the occurrence of certain series lines and their relative excitation levels and to obtain improved wave-lengths of certain lines whose presence in the solar spectrum has been uncertain. The band spectrum of calcium fluoride was also photographed for comparison with the sun-spot spectrum; the appearance of these bands in the spot spectrum would show the presence of fluorine. While some coincidences were found, a check with plates of higher dispersion is desirable.

ANALYSIS OF COMPLEX LINES OF PRASEODYMIUM

During the summer of 1928, Dr. Harvey E. White, of Cornell University, made a study with high dispersion of the stronger lines of ionized praseodymium, previously shown by King to be very generally of complex structure. The photographs, which extended from λ 3200 to λ 6800, were made chiefly with the 75-foot spectrograph on Mount Wilson, the dispersion being 1.5 Å per millimeter. Good resolution of the complex lines, usually of six components each and of different types of spacing, was obtained, and the material will be of much service in grouping the lines for analysis of the spectrum. A description of the lines was kindly furnished to King, supplementing the data being published on the praseodymium spectrum. Work on this spectrum is being continued by Dr. White at the Reichsanstalt

in Berlin, and also, during the present summer, by Professor Gibbs and Dr. Gartlein in the Pasadena laboratory.

A NEW ISOTOPE OF CARBON

A faint band structure with its head at λ 4744.5 has been observed by King on many spectrograms made with the high-temperature furnace which also show the well-known Swan bands. Proximity to the strong band at λ 4737 suggested that the faint band might be due to a carbon isotope associated with the regular carbon atom of mass 12 in a certain proportion of the diatomic carbon molecules. This hypothesis was tested by means of the new theory of band spectra, which has been successful in detecting isotopes of several elements, and, during the last year, has demonstrated the complexity of oxygen. The test for a carbon isotope was carried out with the cooperation of Professor R. T. Birge of the University of California. The intervals between the heads and between corresponding lines in the main band and in that of the suspected isotope led to practically the same frequency difference. The use of this difference in connection with the known constants of the band structure gave conclusive evidence of a carbon isotope of mass 13 as the origin of the faint band.

Confirmation of the existence of this isotope was immediately obtained by Birge from measurements which he had previously made of faint lines in the cyanogen bands appearing on furnace spectrograms obtained by King and of a long series of bands in Hopfield's ultra-violet spectra of carbon monoxide.

Besides the discovery of a carbon isotope, of which the relative abundance will be estimated by means of further experiments, the investigation furnishes another example of the effectiveness of band-spectrum analysis in detecting isotopes occurring in small proportions, as they probably do in many chemical elements. It also establishes diatomic carbon as the origin of the Swan spectrum of carbon, a question long in controversy. The rôle played by moderate excitation like that of the furnace in producing relatively strong radiation of such an isotope is a question for further investigation, and is of much interest in connection with the probable occurrence of the carbon isotope band with high intensity in the spectra of N-type stars.

HIGH-CURRENT DISCHARGES IN VACUUM TUBES

Anderson has continued the experiments on high-current discharges in vacuum tubes, using a fused-quartz tube with a very short and small-bore capillary section, in order to extend the observations reported last year to higher current densities. With this tube 3,000,000 amperes per square centimeter in the capillary section could easily be obtained, without danger of breakage. The capillary had initially an interior of 1 mm., and when viewed side on it emitted a continuous spectrum, if the current density was 100,000 amperes per square centimeter or more. At current densities of 300,000 to 3,000,000 amperes the quartz vaporized rapidly, thus increasing gradually the bore of the capillary. The tube was operated at these high densities until the bore measured 6.5 mm., when it was taken down and examined. The inside surface of the capillary was found to be smooth,

highly polished, and without any trace of fine surface cracks, such as are always found in glass tubes similarly treated.

The observations had indicated that a considerable amount of gas was evolved with each heavy discharge; to study this further a new capillary was inserted and another run was made, during which the quantity of gas evolved was measured. The gas proved to be oxygen, and when the bore of the capillary again reached 6.5 mm., the quantity of quartz evaporated was computed from measurements on the increased volume of the capillary section. The oxygen contained in the evaporated quartz equalled the amount of gas evolved, well within the limit of experimental error, which was about 10 per cent. Examination of portions of the discharge tube which were away from the path of the discharge showed them to be covered with a hard, black deposit which proved to be silicon. It is accordingly clear that when very heavy discharges pass through a constriction in a quartz tube, where the current density is greater than 300,000 amperes per square centimeter, quartz is evaporated from the walls and completely dissociated into silicon and oxygen.

An examination of the spectrum of various parts of the tube showed the low-temperature silicon lines as fine absorption lines in the continuous spectrum from the capillary, and as bright lines of Si I, II, III and IV in the parts of the tube away from the direct discharge.

At current densities of the order of 100,000 amperes per square centimeter there is little or no disintegration of the quartz walls of the tube. Consequently the gas pressure must be sensibly that of the residual gas in the tube before and after a discharge is passed, which in these experiments was always between 0.1 and 0.2 mm. of mercury. It follows that a gas at this pressure, in a layer 1 mm. thick, and sufficiently ionized to carry 100,000 amperes per square centimeter, is opaque.

WIRE EXPLOSIONS

A series of observations of electrically exploded wires was made by Anderson with the aid of the magneto-optic shutter in order to learn what happens at the moment when the wire is just completely evaporated. Previous work, reported in Contribution No. 323, showed that instead of the smooth small cylinder of vapor that one would naturally expect, a great number of irregular jets project at right angles to the direction previously occupied by the wire. A much more extended series of observations shows this to be characteristic of all the metals except tungsten. With tungsten smooth cylinders are obtained, showing only very faint traces of the jets. It was also found that the irregular jets are the more prominent the lower the boiling point of the metal studied. The explanation is undoubtedly as follows: As long as any of the wire remains, the current has a relatively low resistance path; but when evaporation is complete, the resistance depends upon the degree of ionization of the cylinder of vapor. If the ionization is slight, as is to be expected with metals having boiling points below 4000° C., the resistance must be enormous, and the discharge must break through as in an ordinary spark. The jets are therefore nothing but the transverse striations always seen in a spark discharge. As soon as the current passes freely, the relatively smooth cylinder again forms; but since

an appreciable interval has elapsed, it will be rather large in diameter, from a centimeter down to a few millimeters, depending upon the boiling point of the metal. Since the boiling point of tungsten is given as 5500°C ., it is to be expected that the ionization would be sufficient to allow the current to pass rather easily, and the smooth small cylinders seen with tungsten wires show that such is the case.

NEON LAMPS FOR COMPARISON SPECTRA

Tests of low-voltage commercial neon lamps made by Babcock to ascertain their value as sources of comparison spectra have brought out features concerning impurities in the neon which warrant further study. One lamp excited by 110-volt alternating current shows numerous lines belonging to the red spectrum of argon and certain lines of helium; another requiring 220 volts shows lines of the blue spectrum of argon, of helium both normal and ionized, the Balmer lines of hydrogen, numerous lines of molecular hydrogen and several lines not yet identified. Many strong lines of H_2 are not found, however, whence it is evident that the conditions of excitation in the 220-volt lamp differentiate the band spectrum of hydrogen. The presence of ionized argon and helium may indicate that the observed H_2 lines are those associated with high-energy levels in the hydrogen molecule. For a 10-inch camera with one prism the impurity lines provide a valuable comparison spectrum from ultra-violet to blue.

RADIATION FROM THE MERCURY ARC

The measurements made by Pettit during 1927-8 on the radiation from the mercury arc as a whole, from the line spectrum, and from the region $\lambda 0.29\mu$ to $\lambda 0.31\mu$ have been repeated with other lamps in order to obtain more representative data. The variation among lamps of different makes and designs is not so great as was supposed, but large differences were found in the effectiveness of the aluminum reflectors supplied with the lamps.

PHOTOELECTRIC CELLS

The properties of a number of photoelectric cells have been studied by Pettit to determine their suitability for use in photometers. The voltage-sensibility curves and current-intensity ratios of sodium, potassium, and caesium, in both gas-filled and vacuum cells, have been obtained. The effect of the intermittent light on the proportionality factor of a rotating sector was investigated, and a small but definite effect was found, the observed deflections being smaller than the sector factor would indicate. The speed of the sector seems to have no important effect. Since the sector is used in photoelectric amplification, the properties of the photoelectric cell under the action of intermittent light are being examined further.

THERMOCOUPLES

A number of thermocouples and thermopiles have been made by Pettit for various purposes during the year. A very simple type, consisting of a copper strip 1μ thick, to the ends of which are fused the couple metals, is very sensitive, but subject to greater drift than the usual form. An element made by attaching strips of this form to a six-junction pile with white lead is very steady, but its heat capacity is greater than that of a separate-

junction pile. Methods have been devised which materially reduce the labor of constructing the separate-junction piles.

DEVELOPMENT OF RADIOMETERS

In an attempt to develop a sensitive radiometer useful for astronomical work, Smith constructed a number of fairly rugged instruments of the shielded-vane type having mica vanes and studied their sensitivity in various gases. It was found that the monatomic gases form more efficient atmospheres than do the diatomic gases, neon being the best.

Before attempting to construct a high-sensitivity radiometer, the most sensitive of the rugged radiometers was dissected and the moment of inertia of the separate parts determined to be as follows: vanes 64 per cent, mirror 30 per cent, staff 6 per cent. To gain definition a large mirror is desirable; but if its moment of inertia exceeds 50 per cent there is a serious loss in sensitivity. Hence, a mirror having a moment of inertia between 30 and 50 per cent of the total seems a reasonable compromise.

The mirror used (1 mm. \times 1 mm., about 90μ thick), while satisfactory for the system just described, is too heavy for a lighter, more sensitive radiometer. Extremely light mirrors may be made by a number of methods, but generally these produce surfaces which give a bad image. Since good definition is desirable, trials were made with glass, quartz-glass, crystalline quartz, mica and calcite. Beryllium showed some promise, but this material has not yet been given a real test. Further work also remains to be done with mica. Of the other materials, calcite proved best, and mirrors of this material are being used on the most sensitive radiometers thus far constructed.

The best material for vanes found thus far is mica, split into sheets one wave-length in thickness. The wings of various insects were tried, the most satisfactory being from fruit-flies kindly supplied by Dr. Bridges of the California Institute of Technology. It was found possible, however, to make vanes of mica which are both lighter and stronger than those made of any of the wing material tried. As an example, Abbot gives the weight of his fly-wings as 0.0085 mg. per square mm., while the mica used averages 0.0032 mg. per square mm. A curious difference appears in the weight of the blackening material. Abbot found this to be 0.035 mg. per square mm., while that used by Smith is roughly 0.0005 mg. per square mm.

The sensitivity of the best radiometer thus far made compares favorably with other instruments. Under conditions similar to those described by Abbot, it gave a deflection of 1270 mm., while Abbot's radiometer showed 80 mm. With allowance for the difference in period, the relative sensitivity is 300 to 80.

An attempt was made to determine the effect of bringing the gas surrounding a radiometer down to liquid-air temperatures. Because of technical difficulties, this experiment failed; but a new case is being built which should clear up this point.

OPTICAL TESTING

In collaboration with Mr. Russell W. Porter, Anderson has compared Ronchi's method of optical testing with the familiar Foucault knife-edge

test. The results indicate that Ronchi's method is fully as sensitive as the knife-edge test, and much more convenient to apply since a darkened room is not necessary.

THE RULING MACHINE

The ruling machine now seems to be in very good adjustment, and during the year a number of 4-inch plane gratings suitable for use in spectro-heliscopes have been ruled by Jacomini. Some trouble has been experienced with metal blanks, and a number of new alloys containing small amounts of nickel have been tried. A local foundry has recently succeeded in making very good speculum castings, however, and for the time being these will be employed.

MICROPHOTOMETERS

Pettit has tested the fidelity of registration of the thermoelectric microphotometer by counts of silver grains in a microphotograph of the pair of iron lines at λ 5273. The mean dimension of the grains was estimated, and individual weights were applied to correct for variable opacity. The transmission curve across the lines determined from the counts of silver grains fits the microphotometer curve very satisfactorily.

Increased ground vibration has necessitated the construction of a more elaborate Julius suspension for the galvanometer than that previously used. A three-stage suspension now gives about the same protection to the galvanometer as was afforded by a single suspension eight years ago.

The relative advantages of the photoelectric cell and thermocouple when used on the same circuit have been studied. With the same galvanometer period and damping, the thermopile shows less curve distortion. When operated on a galvanometer circuit the photoelectric and thermoelectric sensitiveness are about the same, unless an amplifier is used with the photoelectric cell.

When used on the same plate the 48-mm. microscope objectives were found to give greater transmissions than the 16-mm. objectives. This phenomenon seems to be due to increased scattering near the slit image caused by the wide angle of the shorter-focus objectives.

Two additional photometers have been designed during the year. One of these has been completed and a third has been re-constructed.

THE VELOCITY OF LIGHT

Tests made during the summer of 1928 bearing on the possibility of measuring the velocity of light between stations on Mount Wilson and Mount San Jacinto, a distance of 82 miles, and between Mount Wilson and Santiago Peak, a distance of about 50 miles, gave little promise of success owing to atmospheric haze and smoke and the lack of definition of the image. Accordingly Dr. Michelson turned his attention to a plan which he had long considered of using a line of pipe from which the air could be exhausted down to a pressure which would insure good conditions of seeing. *

Experiments carried on by him at the University of Chicago during the winter showed that multiple reflections from mirrors at the two ends of the pipe line might be expected to give satisfactory results. Funds for the investigation were provided by the Carnegie Corporation and the Rocke-

feller Foundation of New York, and with Dr. Michelson's return to Pasadena in May preliminary investigations were begun. Through the courtesy of the Department of War, permission was obtained to use a portion of Ross Field at Arcadia. The apparatus was set up in the open air, and the stability and the adjustments of the mirrors were tested by reflecting a beam of light several times over a distance of 1000 feet.

The results of this preliminary study, though influenced seriously by atmospheric disturbances, have been such as to justify beginning work upon the pipe line. Since the final measurements will require a length of one mile, it has been necessary to find another site, the size of Ross Field being insufficient. Such a site has been selected, and 1100 feet of corrugated steel pipe 3 feet in diameter have been ordered. This will be set up in permanent form with the 60-foot sections joined by air-tight connections. The entire apparatus will then be installed, the pipe exhausted of air, and complete tests made of its operation. If these prove to be satisfactory, the remainder of the mile of pipe will be purchased and attached to the 1100-foot length already in use.

REPETITION OF THE MICHELSON-MORLEY EXPERIMENT

The report of last year gave the general results of the first two series of measurements made by Dr. Michelson, Mr. Pearson and Dr. Pease with the large interferometer designed to investigate a possible ether-drift. A third series was then made with the length of the path of light increased to 85 feet, and the instrument placed in a completely enclosed underground room where temperature changes are extremely small. The results showed no displacement of the fringes as great as one-fiftieth of that to be expected on the supposition of an effect due to a motion of the solar system of 300 km./sec. The observations were made over a range of sidereal time calculated to insure the maximum effect.

It is hoped that the observations may be repeated on Mount Wilson inside the large pier supporting the 100-inch telescope where temperature conditions should be excellent.

CONSTRUCTION DIVISION ENGINEERING AND DESIGN

The design of instruments and apparatus has been carried on by Pease and Nichols, and H. S. Kinney has completed most of the working drawings for the instrument shop. During the latter part of the year Nichols has taken over most of the work of design, Pease devoting the principal part of his time to observing and to plans relating to the 200-inch telescope.

The design and full working drawings for the following instruments have been completed during the year: a new registering microphotometer; two spectrohelioscopes, one for use in the 60-foot tower telescope; a small quartz spectrograph; a stellar comparator; a small thermocouple measuring machine; a concave-grating spectrograph of the Eagle type of mounting; apparatus for measuring the intensity of radiation at a total lunar eclipse; a new driving clock for the Solar Laboratory; mirror mountings and much apparatus for the investigation of the velocity of light; and numerous attachments and small instruments for the physical laboratory and the telescopes on Mount Wilson.

INSTRUMENT SHOP

The work of the instrument shop has continued under the superintendence of Alden F. Ayers. More time has been given to the construction of the 50-foot interferometer than to any other instrument. The vacuum spectrograph, Cassegrain stellar spectrograph for the 60-inch reflector, driving clock and other apparatus for the Solar Laboratory, several spectro-helioscopes, and instruments for the measurement of radiation have been important features of the construction work of the year. A small quartz spectrograph for use with the large reflectors and a 1-meter concave grating spectrograph for the physical laboratory have been completed. Much work has been done on the new microphotometer, and a modified Julius suspension has been built for the galvanometer of the present instrument. The instrument shop has also carried on construction work for Dr. Michelson's measurements of the ether-drift and the velocity of light, and has assisted in some of the experimental work relating to the 200-inch telescope.

OPTICAL SHOP

In the optical shop W. L. Kinney has figured two 22-inch plane mirrors for use in the measurement of the velocity of light, a large prism of ultra-violet glass for the coude spectrograph, a 6-inch objective prism for the Solar Laboratory, and several sets of mirrors and lenses for the spectro-helioscopes. Dalton has figured many speculum plates of 4 to 10 inches diameter for use in the ruling machine, and has made many small lenses, mirrors and plane-parallel plates of glass, fused and crystalline quartz, pyrex, calcite and other materials. He has also completed several fused-quartz test planes for use in the optical shop.

In preparation for the great amount of optical work involved in the construction of the 200-inch telescope, two men have been taken into our shop to receive their training under Dalton and Kinney. They have devoted their time to learning methods of optical testing and the grinding, polishing and figuring of mirrors and lenses. They have also made some apparatus for the California Institute of Technology. Dalton has overseen the design and erection of a 4-unit 8-inch grinding machine for the 200-inch telescope optical shop, and has refigured one of the objectives used in the tests of seeing at the proposed sites for this instrument. Kinney has rough-ground a 22-inch fused quartz disk obtained from Dr. Elihu Thomson in the course of his preliminary work leading up to the construction of the 200-inch mirror, and has carried on tests on the grounds of the California Institute of Technology to determine the effect of earth vibrations on the new optical shop planned for the 200-inch telescope.

CONSTRUCTION, MAINTENANCE AND OPERATION

Most of the work of the year on Mount Wilson has been of the nature of improvements and maintenance of the buildings and equipment, and little new construction has been done. The interior of the Museum has been modified and refinished, and the exhibit of astronomical photographs has been greatly improved through the work of Hickox. The dome and building of the 100-inch telescope have been painted with aluminum paint, previous experience with the 150-foot tower having shown that this material is well

adapted to resist weather conditions on the mountain. The decision of Dr. Michelson to discontinue further measurements of the velocity of light between mountain stations, and to use a pipe line exhausted of air for future work, has made it possible to dismantle the temporary buildings erected on Mount Wilson. Two of them can be utilized at the new site selected in the valley for the continuation of the investigation.

The construction work has remained under the charge of George D. Jones, our superintendent for many years. Owing to illness, Mr. Jones has been on leave of absence during a portion of the year, and it is hoped that he will soon be able to return with his health completely restored.

Merritt Dowd, engineer, and Sidney Jones, assistant engineer, have maintained the operating plant on Mount Wilson and have designed and constructed much accessory electrical apparatus, including a most successful temperature control for the large concrete room at the coudé focus of the 100-inch reflector.

Two successive seasons with a precipitation less than two-thirds the normal have shown the necessity for adequate water-storage facilities on Mount Wilson. With the present reservoir capacity of over 700,000 gallons, and the deep well which was constructed about three years ago, there is little reason to fear a water shortage except under extraordinary conditions. A fire patrolman has been maintained during the summer months through the cooperation of the Forest Service and the Pasadena and Mount Wilson Toll Road Company, with a station on the Observatory property near the 100-inch telescope building.

THE LIBRARY

On June 30, 1929, the bound volumes in the library numbered 10,314; the number of pamphlets was about 6500 and of lantern slides about 2500. Between July 1, 1928, and June 30, 1929, the library acquired 254 bound volumes, of which 83 were by purchase, 106 by binding, and 65 by gift. During 1929, 114 periodicals and transactions of learned societies have been received, of which 33 are exchanges.

NUTRITION LABORATORY¹

FRANCIS G. BENEDICT, DIRECTOR

Aside from the intensive experimental program carried out at the Nutrition Laboratory and at cooperating institutions, the most outstanding extra-laboratory activity of the past year was the triennial tour of European institutions by the Director. An especially appreciated feature of these tours is the fact that, through the generosity of the Carnegie Institution of Washington, it is possible for a representative of the Institution to give, without honorarium or any expense to the European laboratory or university visited, a lecture dealing with the latest advances made by the Nutrition Laboratory in its researches on nutrition. In the belief that a laboratory representative could with better grace ask in other laboratories to see the results of unpublished work if he brought with him records of similar character from the Nutrition Laboratory, it has been the custom in the last five tours for our representative to have in hand a lecture, copiously illustrated with lantern slides (charts, tables and photographs of technique), reporting exclusively the results of unpublished researches. Frequently this lecture has been given immediately upon arrival in a city, before the various clinics and laboratories have been visited. Presentation of our unpublished work by means of such a lecture has had the double advantage of showing our foreign colleagues the last pages, as it were, of our laboratory notebooks and of stimulating questions, suggestions, and even keen adverse criticism, which have enabled us to correct errors and to modify our method of attack whenever necessary.

As a whole, the lectures have been well attended, for although the discussion has invariably concerned a highly specialized subject, the audiences have always been of unexpected size. Our foreign friends have interpreted as an act of international friendship the fact that an American would come to Europe and present for the first time to a European audience the results of unpublished researches. The openly expressed appreciation of these lectures has been most gratifying. Indeed, both in governmental and in diplomatic circles unexpected recognition has been received. Thus, in view of the nature of the lecture trip, diplomatic assistance was offered and rendered by the embassies of Germany, Austria, Hungary and Jugo-Slavia in the form of visas and special advices to the frontier officials. At Paris the address was given under the auspices and under the presidency of Senator Rouge. In Belgrade the speaker was introduced by the American Minister, the Honorable J. Dyneley Prince, and at Hamburg a representative of the American Consulate was present. In Hamburg also the University's appreciation of the work of the Carnegie Institution of Washington, as a whole and its recognition of the Institution's friendly efforts towards establishing close scientific contacts were materially expressed by presentation of a gold honor medal to the Director on the part of the Faculty of Medicine.

¹ Situated in Boston, Massachusetts.

It has frequently been stated by Europeans that this series of lectures has had appreciable weight in the great problem of re-establishing international scientific amities, not only between the United States and the several European countries but to a certain extent between the various Continental countries themselves. A further opportunity for cementing the ties between the Nutrition Laboratory and other institutions was had during the foreign tour through more or less formal speeches in connection with social functions. On such occasions it was deemed proper to emphasize the debt which America owes to European centers of research, to cite specifically instances when valuable suggestions had been received locally, and to stress the importance of capitalizing the broad ideals of men in the medical sciences as an approach to the mutual understanding of various peoples.

The idealism of men who are working solely for the advancement of health and the betterment of humanity, receiving often the merest pittance and never a large stipend, is an idealism held equally by all research investigators in the medical sciences in every country. The absence of jealousies, of commercial competition, and of desire for personal gain in researches of this kind results in a spirit of tolerance and appreciation of the scientific work of other nations which obtains not only in the laboratory but also in the class room and the lecture room and which certainly passes to the student and from him into the home. Lecturing as a guest, it was perfectly proper for the representative of the Carnegie Institution of Washington to emphasize the great service of research workers in the medical sciences and especially their responsibility in furthering mutual good will among institutions of learning. It seems as if these lectures and the incidental addresses of a diplomatic and social nature are carrying out in European countries the great mission of creating international understandings which has been so admirably furthered in maritime ports by the cruises of the yacht *Carnegie*. We may believe, then, that not only our researches but likewise conferences of this kind are fulfilling in a measure the desire of Mr. Carnegie, who wished us to repay in so far as possible the debt which we owe to the Old Country.

COOPERATING AND VISITING INVESTIGATORS

Professor E. G. Ritzman, of the Laboratory for Animal Nutrition at the University of New Hampshire, has furthered the studies on the metabolism of sheep and cows, employing three forms of respiration chamber installed at Durham. In the new quarters made possible by the support of Director John C. Kendall of the Agricultural Experiment Station and President E. M. Lewis of the University of New Hampshire, this cooperative research has been especially facilitated.

Professor Lafayette B. Mendel, of Yale University, has continued the cooperation with this Laboratory in the study of the metabolism of the albino rat. The addition of a constant temperature room and facilities for special handling of the rats have enabled the investigation of many new problems.

Dr. Oscar Riddle, of the Department of Genetics of the Carnegie Institution, has continued his active cooperation in the study of the metabolism

of pigeons and has been responsible for a large share of the preparation and putting through the press of the first report of this investigation.

Dr. F. Strieck, of the Medical Clinic of Professor E. Grafe in the University of Würzburg, spent several months at the Nutrition Laboratory as a result of arrangements with the *Notgemeinschaft der Deutschen Wissenschaft* and the Rockefeller Foundation. Although chiefly occupied in a general survey of the Nutrition Laboratory's methods and problems, Dr. Strieck participated actively in a research on the metabolism during muscular work.

Dr. Julius Nitzulescu, of the Faculty of Medicine, Jassy, Roumania, spent several weeks at the Nutrition Laboratory, through arrangements with the Rockefeller Foundation, occupying himself mainly in studying the technique of the Carpenter gas-analysis apparatus.

The investigators who are cooperating with the Nutrition Laboratory in its studies on racial metabolism have been particularly active. Those who have sent in protocols during the past year are: Professor Eleanor D. Mason, of the Women's Christian College, Madras, India; Professor C. S. Hicks, of the Department of Pathology, University of Adelaide, Adelaide, South Australia; Dr. H. S. D. Garven, of Moukden Medical College, Moukden, Manchuria; and Dr. L. G. Kilborn, of West China Union University, Chengtu, Szechwau, China. Other investigators equipped with apparatus and now in the field, with reports to come in later, are: O. W. Torreson and J. H. Paul, stationed on the yacht *Carnegie*; P. G. Ledig, of the Department of Terrestrial Magnetism of the Carnegie Institution, who is continuing the collection of data at Magnetic Observatory, Huancayo, Peru; Professor Carey D. Miller, of the Department of Household Science, University of Hawaii, Honolulu; and Dr. M. Odin of Umåa, Sweden.

LECTURES

A regular feature of the instruction at the Harvard Medical School has been an annual series of lectures on basal metabolism, given gratuitously by Dr. T. M. Carpenter. On March 11, 1929, Dr. Carpenter also gave a lecture at the Evans Memorial Hospital in Boston on "Metabolism studies with dextrose and levulose."

The Director gave an address before the Yale Medical Society at New Haven, Connecticut, on December 12, 1928, on "Comparative physiology as an aid in studying problems of human nutrition." On December 18, 1928, he lectured before the Harvard Medical Society at the Peter Bent Brigham Hospital in Boston on "The respiratory quotient and its significance."

Some thirty-five lectures were also given by the Director during his foreign tour. Of these lectures the one most frequently chosen covered the recent investigations of the Nutrition Laboratory. A second lecture dealing specifically with the respiratory quotient was delivered in several places, and a general lecture to medical students on basal metabolism was occasionally requested. The first of this 1929 series of lectures was given in Paris before a public audience in the amphitheatre of the Société Scientifique d'Hygiène Alimentaire et d'Alimentation Rationnelle de l'Homme. Other lectures were given at Strasbourg, Lyons, Geneva, Berne, and Zurich.

There were two lectures in Vienna, three in Budapest, and one in Belgrade. In Brno and in Prague the general lecture was chosen. The sojourn in Germany unfortunately coincided for the most part with the regular vacation period; hence lectures were given only at Leipzig, at Hamburg, and before the Medical Society at Dortmund, the site of the new Kaiser-Wilhelm Institut für Arbeitsphysiologie. In Copenhagen the general lecture was given. In Stockholm there were two lectures and in Utrecht two. The general lecture was delivered at the British universities of Cambridge, Oxford, Edinburgh and Birmingham, and in London at Guy's Hospital and at the London Hospital.

INVESTIGATIONS IN PROGRESS

Gas analysis—No one technique in studying the physiology of nutrition, particularly respiration, has in years assumed the importance of the extremely accurate gas-analysis apparatus developed by Dr. T. M. Carpenter from the early model of Haldane. This highly perfected apparatus makes possible an entirely new method of attack on nutrition problems. Consequently, although occupied to a great extent in administrative work in the absence of the Director, Dr. Carpenter has wisely concentrated upon the desired modifications in this apparatus, the methods of testing it, and the conditions for its maintenance in perfect service. Today, therefore, a gas-analysis apparatus has been developed having perfect compensation, with provision for complete saturation of the air sample with moisture, with new reagent reservoirs of large volume and special design, and with closest contact between the gas analyzed and the fresh reagent. An apparatus for more rapid analysis with slightly less accuracy is being developed at the present time, and the use of hydrogen for the determination of oxygen is being investigated. An apparatus for the determination of vapor pressure is also being studied. Dr. Carpenter has been assisted in this work mainly by E. L. Fox.

Metabolism with sugars and muscular work—The course of the respiratory quotient and the total metabolism has been determined after ingestion of levulose and dextrose, at rest, compared with the progress of the same factors when the ingestion of the sugars was followed immediately by one hour of muscular work. The purpose of these experiments of Dr. Carpenter was to determine whether the performance of muscular work would alter the type and the rate of reaction after the ingestion of sugars. The experiments were carried on with the assistance of E. L. Fox and R. C. Lee.

Alveolar carbon dioxide after ingestion of sugars—The ingestion of levulose is followed by a sharp and marked rise in the respiratory quotient, which frequently reaches values above unity. It is of importance to know whether this rise is due to metabolic transformations alone or due to a stimulated over-ventilation. In order to throw light upon this question Dr. Carpenter has determined the alveolar carbon dioxide at frequent intervals after the ingestion of 100 grams of dextrose and of levulose, respectively, compared with the course of the same function when nothing was ingested. E. L. Fox and R. C. Lee likewise assisted in these experiments.

Mechanical device for rapid and exact determination of carbon dioxide—Two pumps, of the type described by Mrs. Cornelia Golay Benedict and

the Director (Boston Med. and Surg. Journ., 1923, 188, p. 567), have been adjusted for the rapid (50 seconds) and accurate (0.01 per cent) determination of carbon dioxide in air samples. A definite volume of gas is transferred from one pump to the other. In this transfer the air passes through an absorbent for carbon dioxide, and the resulting diminished pressure in the second pump is measured.

A simple form of respiration chamber for studying metabolism during light muscular activity, such as typewriting—The chamber consists of two parts, the upper closing into a water seal attached to the lower part. Ventilation is secured by means of a simple blower, which discharges air from the chamber into a dry gas meter. Uncontaminated outdoor air is drawn into the chamber by suction. Precisely the same type of apparatus has been used for studying adult sheep, and a simple change in the dimensions of the chamber makes possible the study of bedridden patients. The apparatus was developed with the help of E. L. Fox and Mrs. Mary Finn Shugrue.

A piston pump for holding gas samples—Collection of dry gas samples during respiration experiments has long been troublesome, involving the use of glass parts and large amounts of mercury. The simple pump described by Benedict and Benedict, with certain modifications by our former mechanician, Mr. Warren E. Collins, has been found to be an admirable gas holder. These pumps are rugged, do not require the use of mercury or glass, and when the washer is suitably lubricated with paraffin oil, E. L. Fox has found that samples of dry air remain unchanged to within a thousandth of a per cent for at least 24 hours.

A helmet apparatus for studying respiratory exchange—The successful use of the helmet in conjunction with the portable respiration apparatus led to the development of an apparatus employing two small blowers, one delivering carbon-dioxide-free air to the helmet and the other withdrawing air from the helmet at precisely the same rate. Samples of the outgoing air are taken by an ingenious device of E. L. Fox, whereby air is allowed to pass through a capillary jet from the main air current into a suspended rubber bag. These air samples are analyzed on the exceedingly exact Carpenter gas-analysis apparatus. The rate of ventilation (read on a domestic, dry gas meter) is so adjusted as to have the air leaving the helmet contain about 1 per cent carbon dioxide. Analyses of air samples taken while an alcohol flame was burning in the helmet gave extremely accurate results for respiratory quotients of burning alcohol, as well as for the total amounts of carbon dioxide produced and oxygen consumed when compared with the theoretical amounts.

Tests of absorbents for carbon dioxide—An extensive series of tests of various special forms of soda-lime was made by E. L. Fox during the past winter. The problem of removing carbon dioxide from an air current without any attempt at weighing it is altogether different from the problem of both removing and quantitatively weighing it. Hence at least two different types of absorbent are necessary.

Studies of the respiratory quotient with resting humans—For two decades the main efforts of the Nutrition Laboratory have been to study the total metabolism, with but relatively little emphasis upon the character of the metabolism as shown by the respiratory quotient. The inherent errors in

the ordinary technique for determining the quotient and particularly in the technique of connecting the subject with the apparatus have deterred us from much work upon the respiratory quotient. With the advent of the helmet apparatus, described above, a new phase of experimentation is before us. Several well-trained subjects have been measured with the helmet apparatus, and it has been established that the respiratory quotient (commonly taken as an index of the character of the metabolism) remains unaltered for periods of at least two or three hours with normal individuals, sitting quietly during the forenoon, and 12 hours after the last food. One subject having an unusually slow respiration rate (three respirations per minute), with whom all prior efforts to determine constant respiratory quotients with several of the well-known methods failed, showed strikingly uniform quotients with the helmet apparatus. Alcohol check tests and physiological check tests, made by E. L. Fox and Mrs. Mary Finn Shugrue, convince us that the helmet provides a perfected method of attack and that the respiratory quotient may assume new significance in the interpretation of metabolism in both health and disease.

Metabolism during muscular work—An investigation was carried out with the cooperation of Dr. F. Strieck of the Medical Clinic, University of Würzburg, dealing with the measurement of the excess of oxygen above the basal amount absorbed during a definite period after cessation of muscular work. By referring this excess consumption of oxygen during a given time to the total oxygen absorbed during the muscular work itself, an effort was made to establish some relationship between these two factors, in the belief that by measuring the excess oxygen consumed after work of various degrees of intensity, it would be possible to predict the oxygen consumption during the work itself. Establishment of this relationship would obviously be of help in solving problems of muscular work during sports and particularly during industrial operations, when it would often be impracticable to connect the subject with a respiration apparatus during the severe work itself.

Direct calorimetry with geese during fasting and over-feeding—The goose can be overfed, the result being a conversion of carbohydrate to fat and a high respiratory quotient. The fasting goose, on the other hand, has a low respiratory quotient. The goose is therefore an unusually good animal with which to study the relationships between direct and indirect calorimetry and especially the caloric value of each liter of carbon dioxide produced and oxygen consumed under these two conditions. A long series of experiments with geese, both during fasting and during overfeeding, was carried out with an electric compensation calorimeter during the past winter by V. Coropatchinsky.

Metabolism of pigeons—In the Department of Genetics at Cold Spring Harbor basal metabolism measurements of pigeons, secured with a multiple-chamber respiration apparatus devised at the Nutrition Laboratory, have become a regular experimental feature, serving as a control upon Dr. Oscar Riddle's studies in genetics, especially dealing with crossing and endocrine changes in pigeons. Certain measurements of pigeons have also been made in Boston with a small respiration chamber, in which the digestive activity, that is, the course of the respiratory quotient following food, was noted and certain important preliminary observations were made on the seeming effect

of light on the metabolism of the pigeon. The research has been under the direct supervision of Dr. Riddle, who has been assisted by Miss Guinevere Christman.

Metabolism of the albino rat—The multiple-chamber respiration apparatus installed by the Nutrition Laboratory at the Laboratory of Professor Lafayette B. Mendel of New Haven has been intensively used by Miss Kathryn Horst in making various studies on the albino rat. The first of these has now been completed, namely, the study of rats during prolonged fasting. The main object of the research has been to investigate the influence of various diets upon rapidity and completeness of growth, involving both stunting and rapid rate of growth. Other factors which have received special attention have been the influence upon metabolism of old age, the effect of several rats huddling together, the influence of the moisture content of the air, of the environmental temperature, and particularly of the temperature for twenty-four hours prior to the metabolism measurement.

Metabolism of large ruminants and of sheep—The reconstruction of the respiration apparatus for large ruminants at the University of New Hampshire in Durham has enabled Professor E. G. Ritzman to make comparisons between the method formerly employed of determining the carbon-dioxide content of the chamber air by aliquoting and weighing, and the newer method of using a dry gas meter and an electric sub-sampling device in connection with the Carpenter gas-analysis apparatus. The agreement between these two methods has been more satisfactory than was expected and will doubtless lead to further simplification of the apparatus. Additional data with regard to the metabolism of steers and cows during lying and standing and the influence of environmental temperature have been accumulated. Similar studies were made on sheep, supplemented by studies of the surface area. In these investigations Professor Ritzman has been assisted by Miss H. M. Hilton, R. M. Batchelder and A. D. Littlehale.

Energy value of foods—Continuing the cooperative investigation on the energy value of foods eaten by college students, Miss A. Gertrude Farr has made several hundred determinations of nitrogen on the collected food samples and has supplemented the earlier observations by a careful dietary study at a sorority of the University of New Hampshire. Considerable time has been devoted to the preparation of an extensive report on the study mentioned in the Director's report of 1927-1928. Director John C. Kendall of the New Hampshire Agricultural Experiment Station has continued his active interest in this research.

Racial metabolism—The contacts in our large racial research are at present chiefly in the Eastern hemisphere and these, together with the European contacts mentioned above, give the Nutrition Laboratory an unusually wide international association in research. A number of workers are now in the field with equipment for studying racial metabolism. Protocols are being regularly received from Professor Eleanor D. Mason of the Women's Christian College, Madras, India, who has found that the race of Tamils show consistently an extraordinarily low basal metabolism. In spite of the almost insuperable difficulties of working with an aboriginal race extremely difficult to approach, Professor C. S. Hicks of the University of Adelaide, South Australia, has succeeded in collecting considerable valuable data,

which are now being computed and tabulated. Professor H. S. D. Garven of Moukden Medical College has sent protocols of his interesting studies with natives in Manchuria. Advices from Professor L. G. Kilborn at West China University report the collection of considerable material, but owing to the difficulties of transit the protocols are to be held until delivery by post is more certain. Professor Carey D. Miller, who shortly returns to the University of Hawaii and contemplates studying the metabolism of the natives and mixed races there, spent some time at the Nutrition Laboratory and received intensive training in the use of the racial apparatus. The Director took occasion on his visit to Stockholm to get in touch with Dr. M. Odin, the director of a large hospital at Umåa, Sweden, who came to Stockholm and was there personally trained in the technique of the field apparatus. Dr. Odin has returned to northern Sweden with equipment and plans for studying the metabolism of that most interesting nomadic tribe, the Lapps. As always, we have enjoyed the helpful cooperation of Professor Abby H. Turner of Mount Holyoke College, who has kindly measured several Indian and Anglo-Saxon students at this college in connection with our racial studies. We are likewise grateful to Professor L. H. Newburgh, who has willingly aided us in securing measurements on certain Indian students at Ann Arbor, Michigan, and to Dr. Leon Jonas of Philadelphia and Professor C. C. Benson of Toronto, for the friendly, cooperative spirit which they have exhibited in this racial research.

EDITORIAL WORK

Articles which have been prepared for publication during the past year and which are soon to appear in print are as follows:

The Carpenter form of the Haldane gas-analysis apparatus. (T. M. Carpenter. *Journal of Biological Chemistry*, July 1929.)

Ethyl alcohol in fowls after exposure to alcohol vapor. (T. M. Carpenter. *Journal of Pharmacology and Experimental Therapeutics*.)

The gaseous exchange of humans as affected by the ingestion of water at 37° C. (T. M. Carpenter and E. L. Fox.)

The gaseous exchange of humans as affected by small quantities of dextrose. (T. M. Carpenter and E. L. Fox.)

The gaseous exchange of humans as affected by small quantities of levulose. (T. M. Carpenter and E. L. Fox.)

The measurement of the basal heat production of pigeons. I: Instrumental technique. II: Physiological technique. (F. G. Benedict and O. Riddle. *Journal of Nutrition*, July 1929.)

The energy and the protein content of foods regularly eaten in a college community. (F. G. Benedict and A. G. Farr. *New Hampshire Agric. Expt. Sta., Bulletin No. 242*, 1929.)

Dernières recherches du Nutrition Laboratory sur le métabolisme chez les hommes et les animaux: le technique employé, les données, et les conclusions. (F. G. Benedict. *Bulletin de la Société Scientifique d'Hygiène Alimentaire*, 1929.)

In addition a bibliography of the publications of the Nutrition Laboratory since its inception has been prepared and is now being printed by the Carnegie Institution of Washington. The editing of these articles has been chiefly in the hands of Miss E. A. Wilson.

PUBLICATIONS

- (1) *Control tests of a Haldane chamber apparatus in the metabolic study of adult alcoholized poultry.* Thorne M. Carpenter. Jour. Lab. and Clin. Med., vol. 14, pages 73-79 (1928).

Control tests with ethyl alcohol were made with a Haldane chamber respiration apparatus suitable for adult poultry. The average percentage recovery for water, carbon dioxide and oxygen in eight experiments of one hour to five hours in duration was 101.8, 98.4 and 99.6, respectively. The average respiratory quotient was 0.659. The mean deviation from average in 29 periods was for water, 4.0; carbon dioxide, 4.5; and oxygen, 5.3 per cent. The mean deviation of the respiratory quotient from 0.659 was 0.016.

- (2) *Acetone as a control substance for respiration and gas-analysis apparatus.* Thorne M. Carpenter, Edward L. Fox, and Arthur F. Sereque. Jour. Biol. Chem., vol. 82, pages 335-343 (1929).

The use of acetone as a substance for control tests for the gasometer apparatus, Benedict universal apparatus, the Haldane portable gas analyzer, and the Haldane-Carpenter apparatus is described. The average ratios of CO_2 to O_2 were 0.746 in 16 periods with the gasometer apparatus, 0.751 with the Haldane portable apparatus when the changes in the air current were 2 per cent or over, and 0.746 with the Haldane-Carpenter apparatus. A mixture of alcohol and acetone gave with the Benedict universal apparatus a ratio of 0.704 as compared with a theoretical ratio of 0.709. The average recovery of the theoretical CO_2 and O_2 values with the gasometer apparatus was 99.9 and 100.5 per cent, respectively.

- (3) *Basal metabolism data on normal men and women (Series II) with some considerations on the use of prediction standards.* Francis G. Benedict. Amer. Jour. Physiol., vol. 85, pages 607-620 (1928).

This second series of basal metabolism measurements includes a number of individuals of unusual configuration and of ages outside the college age. Comparison of the deviations of the actually measured metabolism from the metabolism predicted by the three commonly accepted standards leads to the conclusion that if predicted values for basal metabolism are to be used as criteria for determining medical or surgical treatment (especially in cases of obesity, endocrine disturbances and unusual configuration), the prevailing methods of prediction demand more critical analysis. Use of "hospital normals" for obtaining *physiological* standards is opposed. The present prediction standards for women are believed to be about 5 per cent too high.

- (4) *The basal metabolism of some browns and blacks in Jamaica.* Morris Steggerda and Francis G. Benedict. Amer. Jour. Physiol., vol. 85, pages 621-633 (1928).

The basal heat production of thirty-seven male browns in Jamaica was, on the average, 5.4 per cent below that predicted by the Harris-Benedict standard for white men. Five female browns and eight full-blooded male blacks had a metabolism not markedly different from that of whites in northern latitudes. This suggests that the climate and the diet in Jamaica probably have no pronounced effect upon the heat production.

- (5) *The basal metabolism of Mayas in Yucatan.* George D. Williams and Francis G. Benedict. Amer. Jour. Physiol., vol. 85, pages 634-649 (1928).

The Maya Indian (male), studied in connection with an archaeological expedition to Chichen Itzá, Yucatan, has on the average a basal metabolism 5.2 per cent above the predicted metabolism of northern white men. Since

the sub-tropical climate might be expected to lower rather than increase the metabolism, it is evident that some factor, presumably racial, has asserted itself. Supplementary observations on white members of the expedition before, during, and after a short stay in Yucatan and on other white men and women who had been in Yucatan less than four months indicated that the change in environment was without influence upon their basal metabolism.

- (6) *Age and basal metabolism of adults.* Francis G. Benedict. *Amer. Jour. Physiol.*, vol. 85, pages 650-664 (1928).

The basal metabolism of a woman remained remarkably constant between the ages of 24 and 36 years. With two men during the age range from 30 to 59 years a distinct decrease in metabolism was noted as the age increased. With a third man studied over the same period the effect of age was probably obscured by an increase in body weight and a pronounced improvement in physical condition. These observations, together with an analysis of the subjective impression of these individuals, suggest that with a low basal metabolism there is seemingly a lowered physical vigor, compared with the vitality when a higher metabolism is noted. Intelligent basal metabolism measurements are strongly to be recommended as a part of the annual assessment of one's physical condition.

- (7) *Basal metabolism before and after a summer vacation.* Francis G. Benedict and Mary D. Finn. *Amer. Jour. Physiol.*, vol. 85, pages 665-671 (1928).

Twenty individuals, both men and women, were studied just before their annual summer vacation in August and shortly thereafter. With two the vacation resulted in a higher metabolism. With the others the metabolism was essentially the same before and after the vacation. This finding suggests that the basal metabolism is in general so fixed as to be unaltered by a summer vacation, even when pronounced subjective impressions of betterment in physical and mental health are experienced.

- (8) *The seasonal variation in basal metabolism.* Florence L. Gustafson and Francis G. Benedict. *Amer. Jour. Physiol.*, vol. 86, pages 43-58 (1928).

With a respiration apparatus of the spirometer type the basal metabolism of twenty students at Wellesley College was frequently measured. The data obtained suggest that the metabolism tends to be at a low level in the winter and to rise to a higher level during the spring and summer. In many of the results there is a hint that the metabolism is lowered during the period of menstruation.

- (9) *Normal menstruation and gaseous metabolism.* Francis G. Benedict and Mary D. Finn. *Amer. Jour. Physiol.*, vol. 86, pages 59-69 (1928).

A series of daily measurements extending over two months and including three menstrual cycles was made with a woman previously observed intermittently over a period of twelve years. Since this subject was of unusually placid temperament, in good health, and experienced no pain or discomfort during the monthly period, it is believed that the menstrual factor alone was studied. The outdoor temperature seemed to have no correlation with the metabolism. The pulse rate was usually lowest when the oxygen consumption was low, but the high pulse rates did not occur at the same time as the high oxygen consumption. In general the metabolism was lowest and most uniform during the menstrual period and highest about one week after menstruation ceased. Menstruation would thus appear to be a real factor lowering the metabolism.

- (10) *Le bain neutre et certaines positions du corps comme conditions préliminaires possibles pour les mesures du métabolisme basal.* Francis G. Benedict, Cornelia Golay Benedict and Mary D. Finn. *Annales de Physiologie*, vol. 4, pages 846-861 (1928).

The metabolism was found to be slightly increased by immersion in a neutral bath and, although it fell somewhat after the bath, it did not become lower than that prior to the bath. It is therefore unnecessary and unjustifiable to introduce into basal metabolism measurements, even in a fully equipped hospital, the difficulties incidental to measurements in a neutral bath. In several instances the metabolism was determined with the subject in the customary sleeping position, lying on the back, and likewise lying on the right or left side. But it was impossible to find any position in which the metabolism was lower than that noted when the subject was lying on the back. These experiments again emphasize the fixity of basal metabolism, the difficulty of lowering it by any experimental procedure, and the importance of using in the study of such subtle factors only persons who, when measured under identical conditions from period to period on any one day, show a uniformity in metabolism.

- (11) *Human skin temperature as affected by muscular activity, exposure to cold, and wind movement.* Francis G. Benedict and Hazelene Stedman Parmenter. *Amer. Jour. Physiol.*, vol. 87, pages 633-653 (1929).

Exposure to severe cold, with or without strenuous muscular exercise, results in a lowering of the skin temperature, chiefly of the extremities, a lowering which can not be counteracted even by the large production of heat in the strenuous exercise of winter sports. During short periods of severe exercise, such as walking indoors on a treadmill or walking upstairs, the metabolism may be increased more than five or six hundred per cent, and yet the peripheral temperature will *simultaneously be lowered* temporarily. Even when the skin has been previously cooled by removal of clothing and there has presumably been some restriction of cutaneous circulation, moderately severe muscular exercise (for 5 minutes) may raise the metabolism five or six hundred per cent without causing an increase in skin temperature, as would be expected when provision must be made for increased heat loss. In these experiments the influence of wind movement and of changes in the vaporization of water from the skin were eliminated, in so far as possible. Since these factors were taken into consideration, the most plausible explanation of these alterations in skin temperature following exercise seems to be that we have here to deal possibly with a vasoconstriction of the peripheral vessels, resulting in a temporary transport of blood from the periphery to the muscles, at least in the initial stages of muscular work.

- (12) *Ein transportabler Respirationsapparat für medizinische, anthropologische und andere wissenschaftliche Experimente.* Francis G. Benedict. *Abderhalden's Handb. d. biolog. Arbeitsmethoden*, Abt. IV, Teil 13, pages 1-32 (1929).

Details are given concerning a small, light-weight respiration apparatus which permits the accurate measurement of the oxygen consumption of humans. See abstract in *Carnegie Inst. Wash. Year Book No. 27*, page 162 (1927-1928).

- (13) *Ein einfacher adiabatischer Calorimeter zur Bestimmung der Energiewerte von Brennstoffen, Nahrungsmitteln und Exkreten.* Francis G. Benedict. *Abderhalden's Handb. d. biolog. Arbeitsmethoden*, Abt. IV, Teil 13, pages 33-49 (1929).

A detailed description is given of an electrically heated adiabatic calorimeter, with which any form of bomb may be employed and with which

rapid and exact determinations of the heat of combustion of foods and excreta may be made. The method of calibrating the calorimeter is explained, and an illustration is given of the calculation of results.

- (14) *Der Oxycalorimeter: Eine Methode zur Bestimmung der Verbrennungswärme von organischen Substanzen.* Francis G. Benedict. Abderhalden's Handb. d. biolog. Arbeitsmethoden, Abt. IV, Teil 13, pages 51-80 (1929).

This description in German of the oxy-calorimeter for determining the energy value of fuels, foods and excreta includes details regarding modifications in technique made since the first published reports in 1925. See abstracts in Carnegie Inst. Wash. Year Book No. 24, page 135 (1925) and Year Book No. 25, page 148 (1925-1926). Calibration tests in which the accuracy of the oxy-calorimeter has been controlled by direct combustions in a bomb calorimeter are reported. Typical calculations of results according to the type of respiration apparatus employed are given, and also data regarding the caloric value of pure organic substances, industrial fuels, several types of human foods, animal feedingstuffs and the excreta of both humans and steers.

- (15) *Measurement of the skin temperature of humans.* Francis G. Benedict, V. Coropatchinsky, and Mary D. Finn. Leopoldina (Amerikaband), Berichte d. Kaiserl. Leopoldinischen Deutschen Akademie d. Naturforscher zu Halle, vol. 4, pages 129-145 (1929).

Description of a thermo-electric method of measuring skin temperature, similar to that published by the same authors in the Journ. de Physiol. et de Path. gén., vol. 25, pages 1-14 (1928). See abstract given in Carnegie Inst. Wash. Year Book No. 27, page 164 (1927-1928).

- (16) *The heat production of the albino rat. I: Technique, activity control, and the influence of fasting.* Francis G. Benedict and Grace MacLeod. Journal of Nutrition, vol. 1, pages 343-366 (1929).

A closed-circuit respiration chamber for measuring (usually in 2-hour periods) both the carbon-dioxide production and the oxygen consumption of the rat is described, and the methods employed by other investigators in studying the gaseous metabolism of the rat are listed. The heat production of rats over 4½ months old, measured at 26° C., decreased on the average from 7 to 13 per cent during the first 17 to 24 hours without food, but remained essentially constant thereafter up to the sixty-fourth hour. The effect of a superimposed factor can thus be satisfactorily studied after the rat has been fasting 17 hours. With rats younger than 4 months the metabolism decreased 28 per cent during the first 24 hours of fasting. The younger organism is therefore not so well able to withstand fasting.

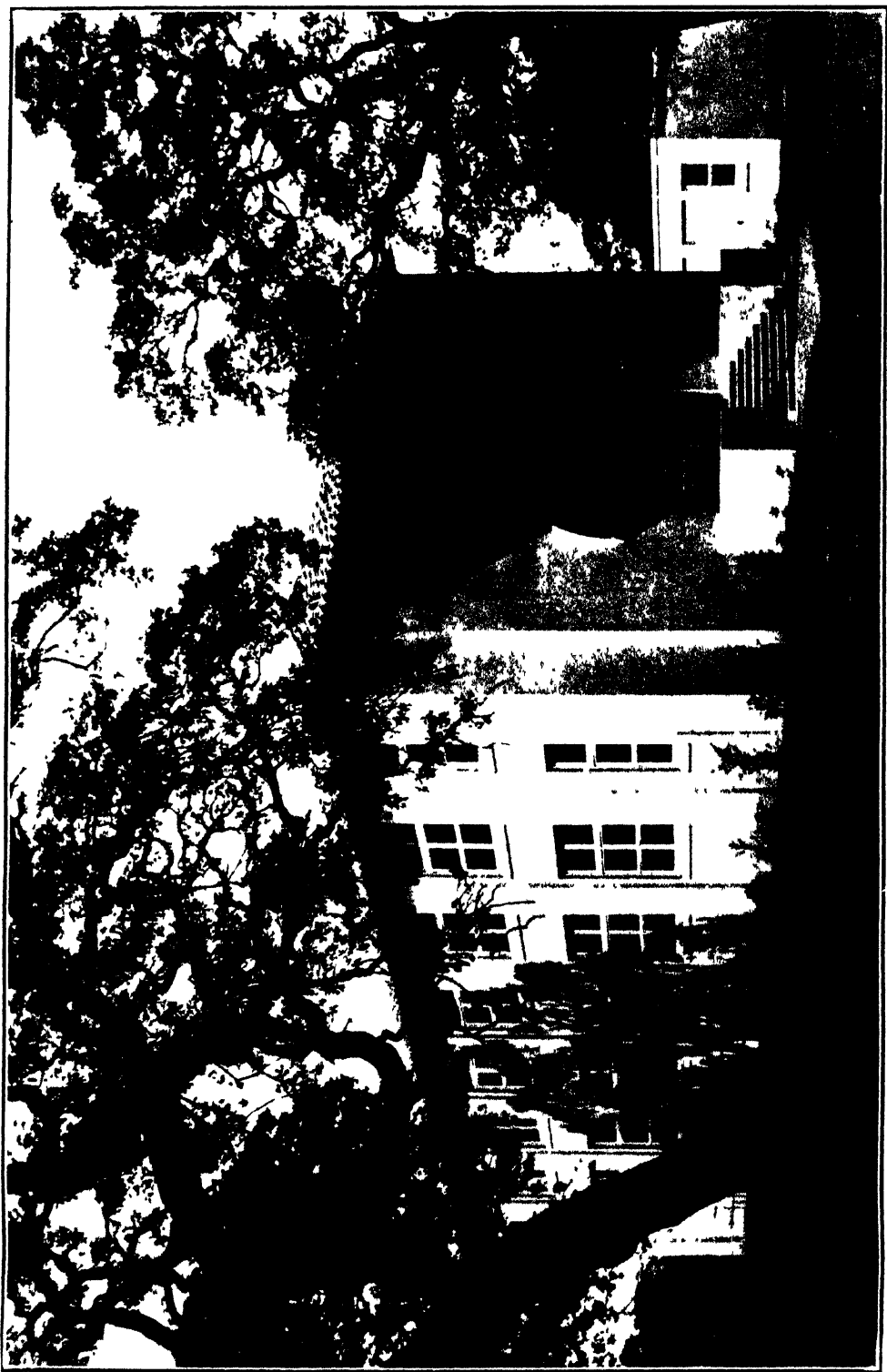
- (17) *The heat production of the albino rat. II: Influence of environmental temperature, age, and sex; Comparison with the basal metabolism of man.* Francis G. Benedict and Grace MacLeod. Journal of Nutrition, vol. 1, pages 367-398 (1929).

The heat production of the albino rat, 17 hours after food, decreases as the temperature becomes warmer and at 28° C. and above is essentially constant. Season has a distinct effect, for the heat production is perceptibly lower (10 to 12 per cent) in the summer than in the winter. Rats studied at 28° C. after living 24 hours at this same temperature have a lower heat production (4.5 per cent on the average) than rats studied at 28° C. after living 24 hours at 21° C. Female rats over 2 months old, not studied during pregnancy or lactation, showed an increasing heat production with advancing age, both at 26° C. and at 29° C. With male rats the data, although not so numerous, indicate the same trend. Male rats have a distinctly

higher metabolism than female rats, up to at least 14 months of age, both at 25° and at 29° C. The female albino rat, 2 months old and over, at 28° C., has a basal metabolism, with cage activity, averaging about 800 calories per square meter of body surface per 24 hours, and with complete muscular repose averaging approximately 720 calories. The basal heat production of male rats of the same ages may be estimated to average about 800 calories, with complete repose. Thus, in spite of its shorter life cycle, small size and high heart rate, the rat has a metabolism on the body-surface basis distinctly low as compared with that of humans. In comparative physiology the influence upon metabolism of both the active mass of protoplasmic tissue and the *stimulus* to this mass should be taken into consideration. The heart rate and the blood volume may possibly serve as approximate measures of this stimulus.

- (18) *Simplified technique and apparatus for measuring energy requirements of cattle.* Ernest G. Ritzman and Francis G. Benedict. Univ. New Hampshire, Agric. Expt. Station, Bulletin 240, May 1929. 30 pages.

This bulletin reports on the progress which has been made in the development of technique and the simplification of design (with accompanying increased accuracy) in apparatus for measuring the respiratory exchange of cattle. Details are included regarding the enlargement of the laboratory building, and several plates and diagrams illustrate the special features of the equipment.



CENTRAL LABORATORY OF DIVISION OF PLANT BIOLOGY

DIVISION OF PLANT BIOLOGY

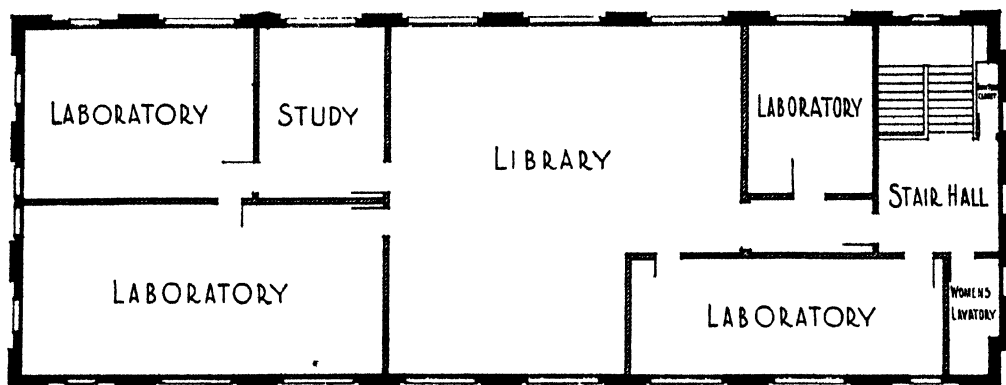
H. A. SPOEHR, CHAIRMAN

During the year covered by this report considerable time has been devoted to the planning and development of headquarters for the Division at Stanford University. After careful study of the entire question, negotiations were concluded between Stanford University and the Carnegie Institution of Washington for a long-term lease of land on the campus of Stanford University. The site is about one-quarter of a mile from the main quadrangle, on the northwest corner of Governors Avenue and the Mayfield-Searsville Road, and adjoining the proposed extensive botanical gardens. It is advantageously located for the utilities, sewer, water, gas, electric power and irrigation water and is conveniently situated in respect to the university scientific libraries, chemical laboratory and herbarium. The site is quite remote from any disturbing influences such as smoke, railways and heavy highway traffic.

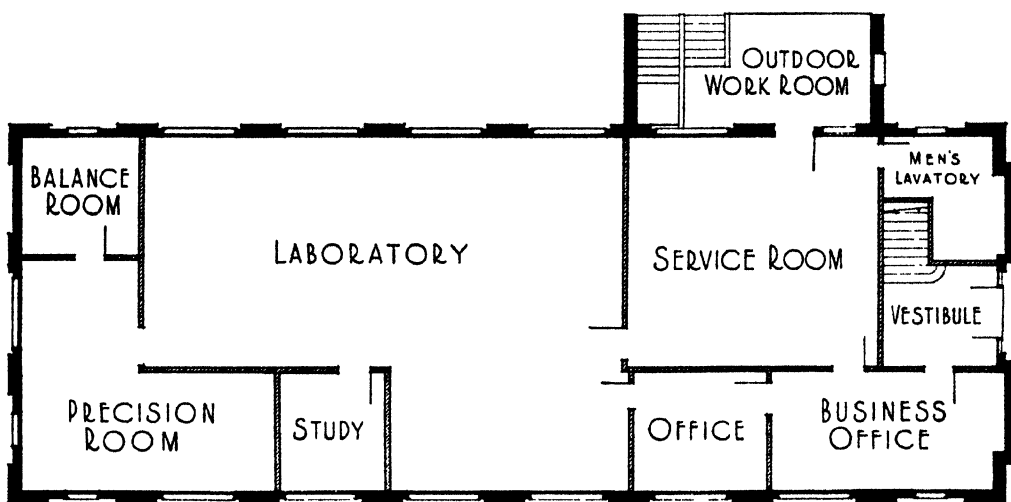
Considerable study was also given to the question of the suitability of the soil for transplant and culture experiments. On most of the area selected the soil is a deep loam, sufficiently fertile, well drained and easily worked. The site of the present developments includes five acres of land and the provisions of the lease make it possible to increase this up to twenty acres as occasion requires.

The present development includes a laboratory building, preparation house, glasshouse with headhouse, lath shelter and about three acres of transplant and culture gardens. In these gardens some material was already planted in the spring of this year. The tentative plans for the laboratory building which had been prepared by the staff of the laboratory were worked out by Bakewell and Brown of San Francisco, architects for Stanford University, and, on approval of the President, the contract for construction was let to George Wagner and Company of San Francisco. Ground was broken January 15 and the building was ready for occupancy July 15. The work of construction was very ably supervised for the Institution by Mr. R. H. Button, Superintendent of Buildings and Grounds of Stanford University.

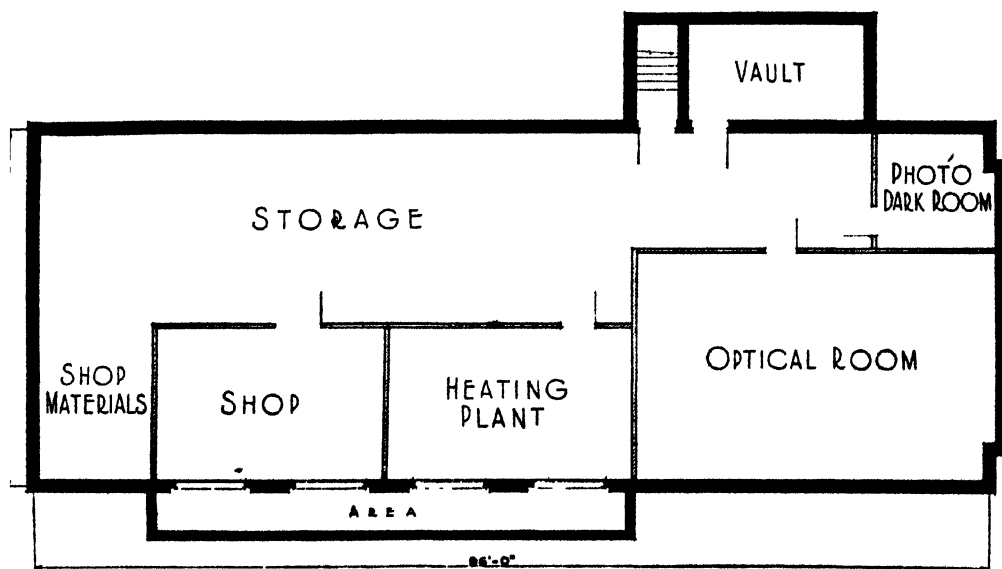
The laboratory building has a basement, 4.5 feet below the ground level, and two floors, each of about 3,300 square feet. The construction is reenforced concrete throughout with some hollow tile and some studded partitions. The roof is of tile. The exterior is buff cement plaster on concrete. The arrangement of the rooms is shown in the accompanying plan. Although the arrangement of the rooms was planned to meet the particular requirements of the research programs now in hand, it was aimed to make the interior construction such that a redistribution of space may be possible, should occasion require, and thus leave the general arrangement of the interior flexible in order to meet the changing requirements of experimental research. All pipes have been left exposed in order to be easily accessible and in many places where plumbing is not now required this has been roughed in. For reasons of economy it was also necessary to omit



Second Floor



First Floor



Basement

installation of laboratory fixtures and furniture in a few rooms. The heating system is hot air from an oil-burning furnace.

The preparation of plant material for the isolation of physiologically important chemical compounds usually requires the handling of large quantities of fresh material. It is often necessary to use tons of fresh plants in order to obtain sufficient chemically pure substance to determine its structure. These processes involve the use of some heavy and noisy machinery and usually relatively large quantities of highly inflammable solvents. For many reasons it was considered undesirable to have this machinery and these factory processes in the main laboratory building. To accommodate this work a separate small preparation house has been constructed of hollow tile. The exterior is cement plaster, but the interior is rough factory construction; it is also provided with heavy-duty utility outlets.

Careful study was given the question of greenhouse construction including location, distribution of space, heating, ventilation, etc. A contract was finally let to the Thompson Horticultural Works of Portland, Oregon, for the erection of the glasshouse. This is 30 by 70 feet, with concrete walls 3 feet high and concrete footings for the pipe-frame benches. The glasshouse is divided into two equal compartments, thus permitting the use of two ranges of temperature. Adjoining the glasshouse but separated by a clear space of 10 feet, a headhouse has been constructed. This is of wood-stud construction, cement plaster on the outside, but for convenience left rough on the inside. It contains three rooms—a soil room, a potting room and a small study as well as a boiler pit with concrete walls and floor. The glasshouse is heated by a hot-water system. The boiler is provided with an oil burner and is of such a type that heat can be supplied to additional glasshouse units whenever new lines of investigation are added to those already under way.

The transplant and culture areas have been well fenced, and that portion designed for immediate use has been piped for irrigation. The first unit of an artificial shade garden has been provided through the construction of a shelter 20 by 40 feet, with lath sides and roof.

The installation of these facilities has permitted the transfer to the new gardens of practically all of the perennial coastal transplants heretofore temporarily held at other stations. About 400 of these are now permanently established in their new location, and in addition 33 collections of annual species are being grown for purposes of taxonomic investigations. Of especial interest is the opportunity for here undertaking experimental studies in connection with members of other scientific institutions. The University of Rennes, the University of Michigan and the U. S. Department of Agriculture are now represented in such studies. Each of these has supplied plant materials used in the experiments and these plants are now growing at the Carnegie Institution station at Stanford University. In every case the results will have a direct bearing upon basic problems with which members of the Division are concerned, as well as upon the special studies of the cooperating investigators.

At the Sierran transplant stations there is noted an improvement in facilities for the growing of cultures under a variety of ecologic conditions. At

Mather, where plants are now grown in five different environmental complexes, there has been an increase in the area covered by artificial shade. A new timber-line station is being established in the Sierra at 10,000 feet altitude. Here all of the alpine and subalpine transplants will be assembled within areas well protected against grazing, burrowing and other destructive animals.

For general work in the garden and on the grounds, the facilities of Stanford University have been at the disposal of the laboratory. This service has considerably expedited and simplified the work of establishing this laboratory and numerous economies have been effected thereby. The work of extending the water, gas and sewer mains was under the immediate direction of the Superintendent of Buildings and Grounds of the University. The laboratory has enjoyed the sincere cooperation of the officers and faculty of Stanford University in many instances since this undertaking was started.

At the Desert Laboratory the "cave" has been completed in the side of Tumamoc hill near the main laboratory and has already proved a valuable addition to the equipment. This stone and concrete structure offers additional laboratory space for special experimentation where controlled temperatures are concerned. Although the temperature can not be maintained constant for long periods of time, it is possible to hold it within 2° F. for about a week.

In the garden adjacent to the office of the Desert Laboratory a lysimeter has been constructed, enclosing 16 cubic meters of alluvial soil, the natural surface and structure of which were not disturbed by the making of the cement sides and bottom. It will be possible to secure with this a continuous record of run-off and of the rate and amount of percolation.

A short section of paving has been laid on the elbow in the road to the Desert Laboratory which completes the paving of the steep part of the road. Additional roads have been cleared and graded on the grounds so that all parts of the fence line can now be reached from the inside. The easy accessibility of all parts of the grounds has resulted in their increased use in the work of the laboratory.

Mr. Godfrey Sykes, a member of the staff of the Desert Laboratory since 1905, retired on June 1, 1929. In addition to his research work along geographical lines Mr. Sykes has supervised the maintenance of buildings and grounds. These duties will be taken over by Mr. Richard Kenny, who has been at the laboratory for twelve years as engineer and shop foreman.

Mr. T. D. Mallery, formerly at the University of Wisconsin, joined the staff of the Desert Laboratory on March 1, 1929, for the remainder of the year. He is working on the mineral nutrition of *Covillea* with particular reference to calcium.

Mr. Ernest H. Runyon, a graduate student at the University of Chicago, spent three months at the Desert Laboratory, as assistant in the summer of 1928. Mr. Runyon was engaged in a study of the seeding habits, germination and reproduction of *Covillea*.

Dr. Eduard Schratz, of the Kaiser Wilhelm Institut für Biologie, has been in residence at the Desert Laboratory since June 1928, as a Fellow of the Rockefeller Foundation. Dr. Schratz has been engaged in work on the

transpiration of desert perennials as correlated with the suction tension of their tissues.

Dr. E. M. Harvey, of Oregon Agricultural College, Corvallis, spent portions of his time during the summer of 1928 at the Desert Laboratory, making studies in the organography of the cylindropuntias, with special reference to the form relations and mechanical equilibrium of the plant.

Dr. A. E. Waller, of Ohio State University, Columbus, spent one month at Tucson in the spring of 1929, with the Desert Laboratory as his base, making a study of the various types of vegetation in connection with his lecture courses in plant geography.

Miss Pauline Mead, a graduate student at the University of Chicago, spent March and April 1929, at the Desert Laboratory, familiarizing herself with methods of field instrumentation suited for use in an investigation of the relation of conditions to vegetation, which she is conducting on the Kaibab Plateau, in northern Arizona. Miss Mead made a comparative study of the conditions in two localities on the grounds of the laboratory, one on the north slopes of Tumamoc Hill and one on the south, involving comparisons of air temperature at two levels, humidity, evaporation, soil, moisture and the temperature of the soil at three depths.

GROWTH

By D. T. MacDOUGAL

Growth in Trees

The dendrographic series begun in August 1918 has been continued. Thirteen instruments have been operated on the Monterey pine in making continuations of records begun several years ago. The changes in diameter of the basal part of tree No. 1 has now been recorded since August 1918 and a second record of a diameter 8 meters above the base was begun in January 1920. The series now includes stems two years old and trunks of mature trees in which the yearly accretion is near a minimum.

Of the interesting phases of growth under experimentation and observation may be mentioned the effects of defoliation. Loss of leaves by this pine kills or exerts a long-continued check on wood-formation. A tree may not recover from the loss of its leaves for five or six years; the effects may be seen for even longer periods.

Loss of large branches or of the leader may be followed by no enlargement of the trunk for as many years. This has also been found in the redwood. Girdling results in the death of the pine and is followed by normal growth of a redwood trunk above the girdle and by diminished enlargement below the girdle.

The end of the growing season of the Monterey pine usually comes in July and is brought about by diminished soil moisture. Trees on high ground consequently show some degree of correlation with the rainfall. Other individuals of the species on the margins of swampy areas or near springs do not give such correlations. Tree No. 17 has shown almost continuous enlargement of the trunk since October 1922; the only interruptions being for a few days late in December 1926 and a second in January 1929 in periods when the temperature of the air fell below freezing point. Eleven

instruments are attached to redwood trees in an ecological series arranged to determine the effect of slope, exposure and soil-water supply. This series includes terminal stems two years old and old trunks several feet in diameter.

Growth in the redwood does not begin until near the end of the winter rainy season. The amount of precipitation in the early part of the winter has but little effect on growth which does not begin until late in the following April.

The season at the Coastal Laboratory has been characterized by high temperatures of the cambium or wood-forming layer in both the pine and redwood. It has been pointed out that, in the three years in which records were kept, the amount of wood formed by the redwood was directly related to the temperature of the cambium. No examination of the meteorological record has been made to determine the cause of the higher readings of thermometers with bulbs thrust under the bark in 1929.

Dendrographic records of some length were made of the tree cactus (*Carnegiea*) of the palo verde (*Parkinsonia aculeata*) and of the poplar (*Populus*) at the Desert Laboratory. It is a matter of note that although dendrographs have been attached to the small green trunks of the palo verde two seasons no record of enlargement has yet been secured. Living cells three or four centuries old may be found in such trunks which may not exceed a foot in diameter. In contrast with most woody trees more than half the volume of such old trunks may consist of living cells. Only a thin layer with a short length of rays are alive in most old or large trees of other species.

Gases in Trunks of Trees

An examination of the composition, hydrostatic condition and communications of the large body of gases which accumulates in trees was begun in 1924. Some details of results of analyses have been given in the annual reports 1925-1928. The extraction of samples is made from bores driven to a depth of 12 to 20 cm. radially into trunks. The original scheme of obtaining samples of about 200 c.c. of gas as described on page 50 of *Hydrostatic System of Trees* (MacDougal, Publ. No. 373, Carnegie Inst. Wash., 1925) has been improved. Gases from the willow (*Salix lasiolepis*), oak (*Quercus agrifolia*), pine (*Pinus radiata*) at Carmel and of the poplar (*Populus macdougalii*) and palo verde (*Parkinsonia microphylla*) have been taken in seasonal series. Oxygen, carbon dioxide and nitrogen are the principal constituents of the samples. The proportion of carbon dioxide may be as much as 40 to 600 times as great as in the atmosphere.

Available results show that the amount of this gas in the tree bears no direct relation to the proportion in the air of the soil. High proportions of carbon dioxide are prevalent during the height of the growing season, while the lowest partial concentration occurs during the resting season. It is by no means clear, however, that the excessive amount of this gas present is of respiratory origin.

Although the strands of water in the ascending meshwork of sap may be under great tension, the "negative" pressure of gases in tree trunks rarely exceeds half an atmosphere. When a greater difference of pressure between

the gases inside the trunk and the atmosphere occurs a flow of gas into the tree takes place, as has been amply demonstrated by numerous pumping experiments.

The communications between the gases in the tracheids and vessels outwardly are through the intercellular spaces in the rays and through the cambium.

The cambium layer is regarded as of the consistency of a liquid by some writers, but the demonstrated communication of the gases in trees radially with the air proves the existence of the intercellular spaces which have been seen by some observers. It is to be noted, however, that these communications might be reduced or closed entirely during periods of intense activity of the cambium.

The fact that the proportion of carbon dioxide rises on days when the outside of the tree is wetted by rains suggests stoppage of minute spaces with liquid through which the gas may pass only by diffusion.

Gases appear to pass from vessel to vessel through walls, the spaces in which are too small for the passage of colloidal dyes.

Some concluding tests for the purpose of determining the origin of the gases in trunks and the detection of minor components are planned for 1930.

PHOTOSYNTHESIS AND CARBOHYDRATE CHEMISTRY

The Interconversion of Hexoses by Means of Phosphates, by H. A. Spoehr and Harold H. Strain

The rate of interconversion of different hexose sugars under a variety of conditions has been followed over an extended period of time. Most of these experiments have now been concluded. In water solution with the weakly alkaline disodium hydrogen phosphate at 37° the hexoses undergo slow interconversion. Thus, after 167 days starting with either one of the three hexoses, *d*-glucose, *d*-fructose or *d*-mannose, mixtures having approximately the following composition were obtained:

	Aldoses	Ketoses	Mannose	Glucose
	<i>p. ct.</i>	<i>p. ct.</i>	<i>p. ct.</i>	<i>p. ct.</i>
<i>d</i> -Glucose.....	78	22	2	76
<i>d</i> -Mannose.....	68	32	46	22
<i>d</i> -Fructose.....	39	71	10	29

Fructose undergoes interconversion far more rapidly than either of the aldoses, and mannose more rapidly than glucose.

In the course of these changes there was also observed a decrease in the hydrogen ion concentration of the solutions; the pH of solutions of glucose dropped from 8.28 to 7.42, of mannose from 8.10 to 7.35, of fructose from 8.20 to 7.10. The rate of the interconversion of all of the sugar mixtures decreases with time. It has generally been assumed that the interconversion is due to an enolization of the sugar molecule, and that the velocity of the reaction is dependent directly on the concentration of the free hydroxyl ions in the solution. It has been found, however, that the Lobry de Bruyn-

van Ekenstein reaction occurs even in phosphate solution of neutral or slightly acid reaction. Thus, for example, fructose in solution with a phosphate mixture having a pH of 6.69, kept at 37° for 165 days, was converted into aldoses to about 28 per cent, of which about 8 per cent was mannose. Another fact of importance in this connection is that the hexose molecule undergoes splitting even in weakly alkaline or neutral phosphate solution, so that this type of reaction must also be taken into consideration in the interpretation of the results obtained from the action of weak alkalis on hexoses.

On the basis of extensive experiments on the preparation of glucose from hexoses and invert sugar with lead hydroxide and phosphates, it is evident that no strictly uniform product can be obtained. The preparations of glucose showed a great variation in yield, reducing power and aldose-content. This is due to the fact that glucose is itself affected by weak alkalis resulting in the formation of other sugars; secondly that glucose formation is accompanied by the production of varying amounts of saccharinic acids; and thirdly, in the fermentation process there is formed a certain amount of non-reducing material.

In support of this it has been possible to demonstrate that glucose in solution with disodium phosphate is converted to an appreciable extent into other sugars which are fermentable. A series of experiments in which glucose and invert sugar were repeatedly fermented with carefully washed baker's yeast showed that a residue with only a very slight reducing power and amounting to about 10 per cent of the original sugar is obtained. This residue, which is not glycerine, forms a considerable portion of glucose gum as commonly prepared.

The phenylosazone of glucose, considered as a definite compound m.p. 165°, has been resolved by suitable solvents into four fractions which melt at: 195–207°, 184–190°, 160–170°, 145–150°, having different solubilities. The phenylosazones obtained from glucose, which was prepared with disodium phosphate, had a nitrogen content corresponding to hexose phenylosazone. The phenylosazones obtained from glucose which had been prepared from lead hydroxide could not be purified by recrystallization so as to give good analyses.

Experiments have been under way with a view to determining the position of the carbonyl group in glucose. By means of the cyanhydrine reaction, a glutheptonic acid has been obtained which could be separated only by its basic calcium salt. This was reduced with hydriodic acid and phosphorous to an heptylic acid. The latter was identified as 2-methylhexylic acid by converting it into the corresponding amide. This is direct evidence that in glucose there is present a 2-ketohexose.

*Mutual Interconversion of Glyceraldehyde and Dihydroxyacetone, by
H. A. Spoehr and Harold H. Strain*

Most theories of carbohydrate catabolism and fermentation postulate as a first step the splitting of the six carbon atom chain of the hexose molecule into two molecules containing three carbon atoms. Substantiation of this

view has been based upon the fact that in strongly alkaline solution the hexoses form lactic acid, and that in weaker alkaline solution these sugars, under certain conditions, yield methylglyoxal. Theoretically, glyceraldehyde is the precursor of methylglyoxal which in alkaline medium rearranges to lactic acid. Isomeric with glyceraldehyde is the ketotriose, dihydroxyacetone, and, on the basis of experience in other sugar groups, these two trioses should be mutually interconvertible in alkaline solution. Since, therefore, glyceraldehyde and dihydroxyacetone, even though in a transitory state, constitute the first products in a series of exceedingly intricate chemical reactions comprising carbohydrate catabolism, it is of great importance, for a clearer understanding of this process, to gain more precise knowledge of the chemical nature and reactions of these substances.

On account of their great reactivity, both glyceraldehyde and dihydroxyacetone are difficult to prepare in pure form. Several improvements in the method of preparing glyceraldehyde have already been reported (Year Book No. 25, p. 175); the dihydroxyacetone used was obtained from Germany, but as it is unstable it had first to be carefully purified; it melted at 80° to 81°.

Of primary importance for this investigation are quantitative methods for the differentiation of the two trioses alone and in the presence of hexoses. Owing to the great similarity in chemical properties of the trioses and their condensation to hexoses this is associated with much difficulty. Considerable work has been done on this problem, but entirely satisfactory methods have not yet been devised. The two trioses have about the same reducing power toward Benedict solution: glyceraldehyde has a value 112.2 per cent that of *d*-glucose and dihydroxyacetone 111.2 per cent. The aldo- and keto-hexoses can be quantitatively differentiated by means of titration with iodine according to the Cajori method. This method in its present form was not found to be applicable for the trioses, though some modifications thereof are now being developed which are yielding promising results. Glyceraldehyde is oxidized quantitatively and very rapidly to glyceric acid by the Cajori method. Dihydroxyacetone, on the other hand, was found to differ from other ketoses in that it was also oxidized by the Cajori reagent. The rate of reaction is slow, but large quantities of iodine are reduced, indicating that the carbon chain is split with the formation of smaller molecules of high reducing power. In substantiation of this interpretation of the behavior of dihydroxyacetone toward the Cajori reagent, it has been found that this triose is easily oxidized with bromine and sodium carbonate to carbon dioxide and glycolic acid. It was also found that the reduction of phospho-tungsto-molybdic acid as suggested by Campbell¹ can not be used as a method to differentiate the trioses or to estimate these in the presence of ketoses or other complex sugars which form ketoses upon heating in acid solution. Furthermore, the method which employs the phloroglucinol addition compound of glyceraldehyde, recommended by Wohl and Neuberg,² was found to be of limited value, because the solution must contain nearly 0.4 per cent of glyceraldehyde before an appreciable quantity of the insoluble addition compound was precipitated.

¹ J. Campbell, Biol. Chem., vol. 67, 59. 1926.

² Wohl and Neuberg, Ber. Chem. Ges., vol. 33, 3095. 1900

Quantitative experiments are in progress to determine the nature and rate of the molecular rearrangements of these trioses in weak alkaline solutions, *viz.*, with disodium phosphate and sodium carbonate. Besides the mutual interconversion of the trioses the reactions also involve the condensation of these to hexoses as well as the rearrangement of the trioses to lactic acid with methylglyoxal as an intermediate compound. Although the experiments have not yet been completed, it is apparent that glyceraldehyde is readily condensed to hexoses and is also converted to some extent to dihydroxyacetone, while the latter, under the same conditions, is converted to a slight extent to glyceraldehyde and hexoses. In the presence of phenylhydrazine and disodium phosphate, at 37°, dihydroxyacetone yields glycerosephenylosazone, and methylglyoxalphenylosazone is formed with phenylhydrazine and sodium carbonate. Glyceraldehyde, on the other hand, does not form an osazone when kept for 31 days, at 25°, with disodium phosphate and phenylhydrazine.

Reactions of Methylglyoxal in Weak Alkaline Solution, by H. A. Spoehr and Harold H. Strain

Since the theory of hexose splitting during catabolism is based upon the formation of methylglyoxal as one of the intermediate products and the opinion is widely held that this compound is the precursor of lactic acid and of alcohol, it is important to establish experimentally the reactions of methylglyoxal under various conditions which simulate as nearly as possible those existing in the living organism. The mode of formation of methylglyoxal from hexoses and its reactions in water solution should be subjected to careful study. These problems constitute the basis of an understanding of the chemistry of carbohydrate metabolism in all living organisms.

Methylglyoxal is a very reactive compound, and its preparation in a pure state is associated with many difficulties. As it was desired to obtain it free from any possible contamination with dihydroxyacetone and in larger quantity, the method of preparation described by Fischer and Feldmann¹ was supplanted, after several trials, by the older method of Dennis² on which some modifications have been worked out.

Quantitative experiments are in progress to determine the rate of rearrangement of methylglyoxal in neutral solution and in the presence of sodium carbonate and disodium phosphate. In weakly alkaline solution the rate of lactic acid formation from methylglyoxal is surprisingly low. However, the interesting observation has repeatedly been made that, under these conditions, the methylglyoxal rapidly disappears, although the reducing power of the solution toward Benedict solution increases and then decreases very gradually. The experiments already show that phosphates readily convert methylglyoxal into some compound of high reducing power, the nature of which, however, is still to be determined.

Micro-Chemical Technique, by James H. C. Smith and Harold W. Milner

During this year the methods of Organic Micro Analysis, which were studied in Professor F. Pregl's laboratory in Graz, have been successfully

¹ Fischer and Feldmann, *Ber. chem. Ges.*, vol. 62, 864, 1929.

² Dennis, *Amer. Chem. Jour.*, vol. 38, 583, 1907.

introduced into our own laboratory. A number of difficulties were encountered in the transfer, due largely to differences in the reagents used, but these difficulties have been entirely overcome and the procedures are now routine in our work. Without these methods, some of the work which has been done on the structure of carotin and the transformation of the sugars would have been impossible. Furthermore, we have been able to assist neighboring laboratories by analysing products for them which they have obtained only in very small quantities.

As an illustration of the applicability of these methods the following example may be cited. Palmitic acid, obtained as an impurity in a carotin preparation, was identified definitely by analysis, neutralization equivalent, molecular weight and melting point even though there was available only 10 mg. of material. This would obviously have been impossible with the macro methods as they require ten times that amount of material for any one determination except melting point. Incidentally by this identification, it has been shown that certain recent work on vitamin A and its relation to carotin may be seriously questioned when impurities are so easily incorporated in apparently pure carotin.

The micro methods which have been used to advantage are those for carbon and hydrogen determinations, nitrogen estimation, the ash analysis of salts of organic acids, acidimetry and alkalimetry, molecular weights and methoxyl determinations. The maximum amount necessary for any one of these estimations is 4 mg.

In keeping with these developments, one of the best ebullioscopic methods for molecular weight determinations, the Menzies-Wright method, has also been adapted to the micro technique. Excellent results have been obtained with only one-tenth the quantities of material necessary for the original procedure.

Absorption Spectra of Certain Phenyl Osazones and Related Compounds,
by James H. C. Smith and Harold H. Strain

The methods now available for the analysis of sugar mixtures, such as are obtained in the interconversion of the sugars, are in general very inaccurate and laborious in their application. Any new method which would more quickly and accurately differentiate between the sugars in the presence of each other and their cleavage products would greatly facilitate progress in this field. Since the phenyl osazones are generally the most easily obtainable derivatives of the sugars, it was thought that there might be sufficient variation in the absorption spectra of these to afford identification by this method. The absorption spectra of a series of these compounds were made in the visible region of the spectrum, but for purposes of qualitative identification the results were disappointing, because the curves obtained were so similar that they were scarcely separable. The equation of the mean curve was found to follow the algebraic expression $\log E = \frac{12\,797}{L} - 25.94$ between the wave-lengths 485 and 430 μ , where E is the

absorption coefficient and L is the wave-length in mille microns. Publication of the curves will be reserved until measurements in the ultra violet are made. There may be a possibility of accomplishing the original pur-

pose in this region, judging by the results of E. C. C. Baly¹ and his collaborators on glucosazone and glyoxal phenyl osazone.

The compounds studied were: the phenylosazones of glucose, galactose, glycerose, xylose, arabinose, maltose, and benzil and benzil itself. They were prepared in the usual manner and recrystallized from alcohol and alcohol-pyridine mixture. In every case the resulting compound had the reported melting point. The absorption photographs were made with a Bausch and Lomb spectro photometer, 70 per cent ethanol solutions being used.

Studies on the Structure of Carotin, by H. A. Spoehr, J. H. C. Smith and Harold W. Milner

Physical constants—During the course of the work on the structure of carotin it has been necessary to determine and redetermine a number of its physical constants. In order that these may be available for identification they have been summarized from our most recent findings.

The empirical formula, $C_{40}H_{56}$, has been confirmed by analysis and molecular weight.

	C	H	Mol. Wt.
Theory	89.48	10.52	536.45
Found.....	89.47	10.60	528.00

(Average of three closely agreeing determinations)

Higher melting points than those previously reported, 174° (corr.), have been repeatedly found. Carotin from sun-flower leaves (prepared by W. G. Young) melted sharply at 178.4° (corr.). Carotin from carrot roots has never been obtained to melt as sharply nor as high, but a value of 176° to 176.4° (corr.) has been obtained.

The density of carotin, determined by the isodensimetric method has been found to be 1.009 (15°/4°).

The optical rotation of carotin in carbon bisulfide solution has been observed to be $[\alpha]_D^{25} = -71 \pm 15$ per cent. Kohl had previously reported $[\alpha]_D^{15} = -30.17$ in chloroform solution. Because of the depth of color of carotin solutions, concentrated enough to give a measurable rotation, this determination is very difficult to make.

The heat of combustion was found to be 5538 Kg cal./mol ± 0.36 per cent (in collaboration with Dr. Frances Long).

Chemical reactions of carotin, addition reactions—When a carbon bisulfide solution of carotin is treated slowly with a solution of chromyl chloride in the same solvent, in the cold, an addition compound separates which contains 6 mols of chromyl chloride as is shown by the following analytical data. Theory for $C_{40}H_{56}.6CrO_2Cl_2$: Cr, 21.28 per cent; found 21.97 per cent. The high result may be accounted for by the ease with which the addition product is hydrolyzed by the moisture in the air. When treated with water and distilled, the aqueous distillate gives the characteristic tests for acetaldehyde, but negative tests for acetone.

When an ether solution of carotin is treated with nitrogen trioxide, the solution is completely decolorized and an addition product can be obtained

¹ Baly, Tuck, Marsden and Gazdar, Jour. Chem. Soc., vol. 91, 1572, 1907.

by the evaporation of the solvent. The substance thus obtained can not be obtained in crystalline form, but persists as a glass which decomposes at 80°. It is soluble in the usual organic solvents except petroleum ether.

An addition product with nitrosyl chloride was also obtained by passing dry hydrogen chloride gas into a chloroform solution of carotin and ethyl nitrite. Analysis showed the following composition, C, 46.60; H, 5.29; N, 5.75. No simple addition product could be postulated with this composition.

Atmospheric oxidation of carotin—When carotin is oxidized by the oxygen of the atmosphere at 100°, it has been shown to form volatile oxidation products. Carotin (0.5938g) was weighed into a platinum boat and dry air, free from carbon dioxide, passed over it at 100°. The gasses were passed through an absorption train consisting of an empty bulb, cooled by ice, a calcium chloride tube and a soda lime tube. After ten days the carotin itself had gained 0.0920g, the glass bulb 0.0200g, the calcium chloride 0.1388g and the soda lime tube 0.1018g; a total of 0.3526g or 60.2 per cent. At the end of the second day the platinum boat with the carotin showed its maximum weight. It continued to lose weight until the end of the experiment. The oxidized carotin, left in the boat, was acidic in nature, and gave a neutralization equivalent of approximately 600. A silver derivative was formed which had 16.4 per cent silver. Other experiments confirmed these results in general. There was considerable variation in the silver content of the "silver salt" obtained in different experiments, however.

When carotin (0.5g) in petroleum ether solution was oxidized with air in the direct sunlight, 0.3 gram of a white powder separated which gave on analysis the following results: C, 56.14; H, 6.79; and a molecular weight of 375. This showed that the carotin molecule had been heavily oxidized and split. When the mother liquor from the oxidation was evaporated a turpentine-like residue remained, which gave the correct analytical results for $C_{10}H_{16}O_8$, viz, C, 65.19; H, 8.78.

Ozonization—Carotin dissolved in carbon tetrachloride when treated with ozone, produced electrolytically, was soon decolorized. A white flocculent precipitate separated; this was removed by filtration. On evaporation of the solvent a viscous colorless residue was obtained, which when hydrolyzed showed the characteristic tests for acetaldehyde. No formaldehyde nor acetone were detected in other portions of the same distillate.

When the ozonization of carotin was carried out in chloroform solution, analogous results were observed, except that the hydrolyzed product in this case gave tests for both formaldehyde and formic acid in addition to the acetaldehyde tests.

P-brom-phenyl hydrazine, in acetic acid solution, when added to the hydrolyzed product precipitated a compound, which on recrystallization from ethyl alcohol melted at 168° and showed a nitrogen content of 12.37 per cent.

Oxalic acid was formed by oxidation of the tar, left from the hydrolysis of the ozonide, with potassium permanganate, in alkaline solution. It was identified by analysis of its calcium salt for calcium and its reducing power against acid permanganate.

Oxidation with potassium permanganate—Carotin was refluxed for several hours with potassium permanganate (in 0.2N potassium hydroxide).

The solution was acidified with phosphoric acid and the carbon dioxide, which was liberated, was absorbed and weighed. The amount of carbon dioxide obtained corresponded to 17 mols per mol of carotin used. The volatile acid which came over on steam distillation was identified as acetic acid by its distillation constant and by the formation of its silver salt. Each mol of carotin yielded 1.77 mols of acetic acid.

Catalytic hydrogenation of carotin—The hydrogenation of carotin was undertaken to show the number of double bonds which the carotin molecule contained. Carotin (5.223 gram) was suspended in acetic acid (50 c.c.) and cyclohexane (100 c.c.). Platinum oxide catalyst (0.2648 gram), prepared according to the method of Adams, was introduced. The mixture was then shaken with hydrogen under three atmospheres of pressure. For each mol of carotin initially present, 8.94 mols of hydrogen were absorbed. On freeing the hydrogenated product from solvent and distilling at 2 mm. pressure, a pale yellow oil was obtained which gave on analysis the following carbon and hydrogen percentages: C, 85.80; H, 13.49; molecular weight, 589. This showed that carotin had absorbed 18 atoms of hydrogen and given a compound of the empirical formula: $C_{40}H_{74}$. The oil had the following physical constants: boiling point, 287° at 2 mm. pressure; density $29.2^{\circ}/4^{\circ}$, 0.8828; specific rotation at 15° , $+7.96^{\circ}$; refractive index, 1.4854 at 29.2° ; molecular refraction, 180.28. The high density and molecular refraction indicate that there are two bicyclic rings, probably two thujane rings, in the molecule.

Reduction with aluminum amalgam—Several attempts were made to reduce carotin with aluminum amalgam. The physical properties of the product showed that a reaction had taken place, but the hydrogenated material always totaled about 98 per cent for carbon and hydrogen. The substance therefore was not a pure reduction product of carotin. The color of the "hydrogenated" product was much lighter than that of carotin; the rotation was strongly positive in contrast to the laevo rotation of carotin; it was much more soluble in most organic solvents than carotin, but it could not be crystallized. Analyses indicated, according to the carbon-hydrogen ratio, that four atoms of hydrogen had been added.

*Preparation of d-Mannose from Date Seeds, by H. A. Spoehr and
Harold H. Strain*

The necessity of using relatively large quantities of *d*-mannose in the experimental world of the laboratory and the high market price of this sugar led to the suggestion that it might be prepared more cheaply. The seeds of the edible date are a waste product and can be obtained in enormous quantity at the packing plants in California.

The seeds could be pulverized in a mill only after first soaking them in hot water for several hours. The meal was then dried and the oil extracted with petroleum ether. The oil amounted to about 7 per cent of the dry meal. The meal was then added to ten times its weight of boiling one per cent sodium hydroxide solution and allowed to stand for half an hour, when it was filtered through cloth and washed free of alkali. The meal lost about 50 per cent of its weight by this treatment.

The dried pulp was treated with sulphuric acid according to the method described by Clark.¹ About 10 per cent of the original meal was obtained as crude mannose and on recrystallization about 6 per cent of mannose. However, it was not possible to obtain this in a very pure state, the melting point was 130° to 131° and the specific rotation $[\alpha]_{16}^D = +12.53^\circ$.

It was also tried to obtain the mannose by separating the mannosephenylhydrazone and treating this with formaldehyde according to the method of Browne.² In this way about 15 per cent of the original meal was recovered as mannose, which also melted at 130° to 131°. Computation of costs showed that no economy could be effected by the employment of this method of obtaining mannose.

Utilization of Glucose, and Dihydroxyacetone in Starch Formation by Leaves, by Harold H. Strain

Many leaves are capable of utilizing a wide variety of organic compounds for the elaboration of starch in the chloroplasts. The object of these experiments was to determine whether leaves could form starch from glucose and from dihydroxyacetone. The petioles of freshly severed leaves of the scarlet runner bean, which had been kept in the dark until free of starch, were placed in solutions of the substances to be tested, kept in the dark and the leaves tested for starch after several days. Controls were run with glucose and sucrose.

From 5 to 13.3 per cent solutions of glucose, which had been neutralized with potassium bicarbonate, no starch was formed in the leaves after 135 hours. The results were the same whether the glucose had been prepared by means of lead hydroxide or by disodium phosphate. In every case the glucose solutions caused wilting of the leaves.

The leaves also produced no starch from a 5 per cent solution of dihydroxyacetone. In every case, both in the dihydroxyacetone and glucose experiments, the controls with the same concentration of glucose and sucrose formed starch readily.

EXPERIMENTAL TAXONOMY

By H. M. HALL, DAVID D. KECK AND WM. M. HEUSI

The multitudinous forms of animals and plants, as found in the world today, represent one stage in the history of organic evolution. The arrangement of these forms in such manner as to display their natural interrelationships is the duty of phylogenetic taxonomy.

The high practical value of such a classification has long been recognized, but of still greater importance is the need of a natural classification as an aid in visualizing the present stage of evolution, in tracing the probable steps by which this stage has been attained, and in forecasting the future trend of evolutionary lines. This applies to all forms of life, from the most primitive to man himself.

This ideal of a complete organic classification is obviously beyond the range of man's ability to reconstruct. By building upon principles already established, however, and by adding to these through further exploration

¹ Clark, U. S. Bureau of Standards, Scientific Papers No. 429, 1922.

² Browne, Ber. Chem. Ges., vol. 35, 1457, 1902.

into the unknown, it is possible to approach the desired goal. In a field so vast, it is necessary that the activities of any body of workers be restricted to a particular sector. With the general classification now fairly worked out, at least as regards the higher plants, and with the minutiae of genetic change now being so vigorously investigated by numerous students, one of the lines of attack most promising in results is upon the evolutionary stages intervening between biotypes and true species. Especially important are (1) a ready means of distinguishing between ephemeral modifications and genetically fixed characters and (2) a knowledge of the processes whereby minute variations become so grouped as to yield the successively larger units of the taxonomist's classification.

Discovery of principles of species-formation involves activities of many sorts. Experimental studies in laboratory and garden are essential, and these are now well under way at several of the transplant stations, but it is important also that results so obtained be directly applied to explanation of phenomena as observed under natural conditions. This involves much field research and the preparation of taxonomic revisions of species, genera and larger groups. Progress in these various phases of the taxonomic work is reported upon in the following paragraphs.

General Results From Transplant Experiments

It is only by actual experiment that one can distinguish with certainty between fixed and modifiable characters. Aside from the question of degree of fixation (if such exists) it is obvious from our results that what appears to be the same character may be highly modifiable in one species but unchangeable in another. Hereditary dwarfs, for example, are well known in genetics but are seldom accounted for in taxonomic treatments. In *Achillaea millefolium* these have not been demonstrated and it is certain from experiment that stature in this species is highly modifiable; but in the closely related *A. borealis* the dwarf character is unchangeable. Plants of the latter moved from timber-line, at about 3,000 meters altitude and grown in good soil at 1,400 meters for five years, have not increased their stature over the original 13 cm., although surrounded by plants of *A. millefolium* ten times as tall. Similarly, when plants of typical *millefolium* are transferred from the Atlantic seaboard to California they retain their characteristic cut of leaf, undescribably but positively different from that of the western form with which they have now been growing for nine years. The heavy-foliaged maritime plant of the California coast may be made to simulate the interior one by growing in moist, shaded soil; but in open places, even at the mountain station, it retains almost without change its original characters of compact habit and heavy, thick leaves for at least 5 years. This persistence in characters is quite unlike certain easily modified features in *Symphoricarpos*, *Hemizonia*, and other genera, as recently described (Proc. Inter. Congress Pl. Sci., Ithaca, II.), or in *Potentilla* and *Zauschneria*, as will be discussed beyond.

Correlations between characters modified by the environment are of especial interest to the systematist. Thus if one character undergoes change, its influence upon others will be known and their modifications will not be

erroneously applied as criteria in classification. One of the most regular of these correlations in plants with cut leaves is increased proportional division of the leaves when these are enlarged. This has been noted in the case of annual species of *Atriplex*, especially *A. argentea*, which produce not only much larger but also much more deeply dentate leaves when grown in favorable soil free from alkalies. When individuals of the perennial species of *Potentilla* are transferred from a high altitude to middle or lower altitudes or from arid situations to moist, shaded places, the leaves produced from the same roots in succeeding years increase their areas 4 to 18 times, depending upon local conditions, and this is accompanied by a notable increase in lobing—passing in some cases from merely cleft to parted or even (in *P. breweri*) to the formation of distinct additional leaflets. It is as though rapid growth prevented the tissues from maintaining their original contacts. Similar interdependence of these characters has been demonstrated in a number of genera but with less striking results.

A correlation between size of leaf, density of pubescence, and color of leaf is of common occurrence. The ecologic factors involved have not been determined with certainty but they are undoubtedly those which control vigor of growth. When transplants are made of individuals from less favorable to more favorable habitats, as from xerophytic high-altitude slopes to gardens at moderate altitude; or from dry, exposed places to moist, shaded places without change of altitude, the tendency in many species is to produce larger leaves with less dense pubescence and of greener color. In some cases, such as *Artemisia vulgaris heterophylla*, *A. v. discolor*, and *Potentilla breweri*, the change is so great that without a knowledge of their history most systematists would place the modified form in a taxonomic position different from that of the original plant from which it was derived. The evidence upon which this is based is preserved in the form of photographs and herbarium specimens taken from the plants before moving and again at intervals during their life in the changed environment.

Experiments in the Genus Potentilla

Potentilla is an ideal genus for intensive field and experimental studies. This follows from its richness in species and minor variations, both here and in the Old World; from the detailed taxonomic attention which the genus has already received at the hands of eminent specialists; and from the ease with which large numbers of vegetative divisions may be obtained from a single root, thus permitting a distribution of uniform parts to any desired number of habitats. It is hoped that the group will attract the attention also of geneticists and cytologists, since the chromosomes are not numerous (8 and 16, as far as known), neither too large nor too small for satisfactory study, and since the flowers are of good size.

A criterion of much value in classification is the number of leaflets. This, however, must be used with due regard to conditions under which the plants grow. For example, plants of *P. douglasii* with 5 or 6 pairs when growing under natural conditions at 2,800 meters altitude produce leaves with from 6 to 10 pairs after transplanting to good soil at 1,400 meters and to near sea-level. In similar manner the leaflets in *P. breweri*, a naturally "vari-

able" species, increase from 2 or 3 pairs to 4 pairs when the plants are moved down the mountain. In this modified form the leaflets are more distantly spaced and each is more deeply cleft.

Particular attention is now being given to forms centering around *Potentilla glandulosa*. This is because of their suitability to the study of ecotypes and "small species" in relation to evolutionary processes and because of their confused taxonomy. The more striking have been variously classed as varieties or species but with no certain evidence as to value of criteria involved. The most conservative monographer has united some American forms with the European *P. rupestris* (Wolf, Monogr. Gattung. Pot. 123, 1908), but this he separates from *P. glandulosa* only on basis of color of flowers, an obviously weak character, as indicated by the interposition (in the same treatment) of *P. arguta*, a species intermediate in this character. After extensive field studies it appears very doubtful if any of the American forms have truly white flowers, and transplant experiments prove that the amount of yellowness is rather closely fixed for each of the races. Evidence is therefore accumulating to show that the number of forms distinguishable by color characters is too great to render this criterion of service in classification. Certainly it is not so valuable as others, either overlooked or used for subordinate categories. About 150 transplants of this group are now growing under 10 sets of ecologic conditions at three different altitudes. Results at hand indicate the following characters as fixed: color of flowers, leafiness of stems and inflorescence, mode of branching, shape of leaflets, angle made by sepals and petals with axis of flower, stature (within reasonable limits), and nature of pubescence. The following features are modifiable: vigor as exhibited in vegetative parts, stoutness and consequent direction of stem, size and texture of leaflets, prominence of venation, size of dentations, density of pubescence, and length of hairs (within narrow limits). It is hoped to increase the forms represented in the cultures, especially by additions from other parts of North America and from Europe in order to permit of detailed comparison of evolutionary tendencies in widely separated areas and to furnish a basis for phylogenetic classification.

The studies thus far made on some 10 species of *Potentilla* point toward several conclusions as regards this genus. One of the most obvious is that many of the species, notably *breweri*, *californica*, *dissecta*, *douglasi*, *glandulosa*, *gracilis*, etc., are composites of innumerable variations, some of these fixed, some reversible. The complete classification of these forms and a study of their geographic distribution might throw much light upon principles of evolution. As to present taxonomic arrangement of the species and varieties, there is little to be hoped for in the way of improvement over the several systems already proposed, unless through more intensive field studies, through experimental tests, and perhaps through cytologic examination.

Experiments in the Genus Zauschneria

This genus of the Onagraceæ comprises leafy perennial herbs or low shrubs capable of ready division by root or stem cuttings. It is restricted to western North America, where it ranges from islands off the coast to desert borders in Wyoming and New Mexico and ascends the mountains to altitudes of 3,300 meters or more. From this ecologically diverse area come

a large number of forms, 19 of which have been described as species and varieties although all of these are considered by a few botanists as of one inclusive species. The latest revision (by Miss Hilend, in Amer. Jour. Bot., vol. 16, 58-68, 1929) admits 3 species with a total of 7 varieties. In this, as well as in all preceding accounts of more than one species, the primary division of the genus is based upon width of leaf. Transplant experiments now demonstrate the easy reversibility of this feature without, however, as yet suggesting any other criterion more dependable for purposes of classification.

Cultures of *Zauschneria* were first made along the California transect in 1923 and have since been added to from time to time. Mr. Heusi has made special studies of these during the present year and reports the leaf transformations referred to. The extreme case is of a plant from Lompoc, California, with leaves so narrow (4 to 5 mm.) as to be classed as *Z. californica typica*. When divisions of this were grown in the dry shade garden at Mather it bore leaves so wide (10 to 12 mm.) as to place the form in *Z. latifolia typica*. Changes as great as this have been induced also by growing the plant first in a pot held in moderate light and later transferring to dry shade at a higher altitude. The evidence is preserved in the form of an herbarium specimen exhibiting the two sorts of leaves on a single stem.

Although these experiments prove the ease with which leaf width is modified, it does not demonstrate that all broad-leaved plants are of the same genetic constitution as the narrow-leaved ones. In fact, other experiments, in which both forms were brought into a uniform environment, show that this is not the case. The indications are that the genus comprises but one species in the Linnean sense, that many minute races (biotypes?) are involved, and that taxonomists have not as yet hit upon the best criteria for classification of these. Certainly width of leaf can scarcely be taken as the basis of a primary division for the forms here reported upon. It is hoped that further studies will reveal better characters and at the same time discover some clue as to origins of the various forms.

Studies in the Genus Pentstemon

Investigations have been continued on this attractive group of plants, the detailed studies being made chiefly by Mr. Keck. His field work and garden experiments have covered the available species of the genus, and Section *Saccanthera* has received intensive laboratory and herbarium study. As work progresses the interdependence of field, garden, laboratory and herbarium methods becomes increasingly obvious. The ideal can be reached only when each important hypothesis suggested by one method can be tested by further use of the others. It is physically impossible to be exhaustive in field studies and garden experimentation, but as questions arise from herbarium studies, the more important of these can be subjected to garden test or considered in the field, often with results that are of general application.

The herbarium work in Section *Saccanthera* is now more nearly complete than either the field studies or the experimental results. Accordingly the progress in the herbarium has brought to light hypotheses that require confirmation in field and garden, but it has also raised questions that call for

further investigation in herbarium and library. For example, *Pentstemon heterophyllus* exhibits three striking variations, each worthy of nomenclatorial recognition, but there is a question as to which of two of these was originally described as *heterophyllus*; and until this point is settled it is impossible to determine which of these two requires a new name. The answer lies in examination of the type specimen filed in a European herbarium, if, indeed, it still exists. Solution of the problem therefore calls for application of the herbarium method.

Of especial interest is the relation of *Pentstemon azureus* to its neighbors and the classification of smaller units within the species itself. It occurs in the Sierra Nevada with 5 or 6 readily recognizable forms. The species is found in common with *heterophyllus* in the foothills on the easterly side of the lower Sacramento Valley. In this area *azureus* has an extreme form that is so exactly comparable to one of *heterophyllus* occurring on the opposite side of the valley as to cause much confusion. Experimental work is needed to make clearer both the likenesses and the differences, while further field studies should aid in determining the true boundaries of the species, both geographic and morphologic, as well as their phylogenetic status. Within *azureus* are 3 climatic forms which appear to grade into one another in characters but each has a fairly well-marked zonal position. The recognition of these forms was the result of detailed studies in the herbarium and here also has been worked out a key for their better definition, but this herbarium-made classification requires testing in the field and confirmation or rejection through transplant experiments. Such work is a part of the program for the near future.

A third species of the group here under discussion is *Pentstemon latus*, which occurs the full length of the Sierra Nevada in one or another of its 4 subspecies. One form grows also in the North Coast Ranges, where it bears a striking resemblance to *heterophyllus*, found close by to the south. This suggests a close phylogenetic relationship between these species and a possible origin of one from the other in this district. *Pentstemon latus* is never confused with *azureus* when both are once understood, but there is an area around Lassen Peak, Shasta County, and in adjoining Plumas and Butte Counties where a peculiar form occurs which appears very definitely to be of hybrid origin between these two. The 7 collections studied show a surprising lack of uniformity as compared with any 7 collections in a species exhibiting normal variation. A further peculiarity is that collections are not as yet known of either *latus* or *azureus* from this district, although both are found on the boundaries. This leads to the assumption that the combination-form under consideration originated by hybridization between the two but is now self-perpetuating. Here, again, experimental evidence, particularly of a genetic nature, would have high value in confirming or overthrowing these ideas, conceived in the course of herbarium and field studies as to the origin of a geographic race or subspecies through hybridization.

Cooperative Studies on Environmental Influence

At the request of Professor Pierre Lesage, of the University of Rennes, tests have been made of 12 variations of *Lepidium sativum* which, according to this experimenter, were induced in the course of cultures extending

over a period of 20 years. This testing was undertaken because of attention which the experiment has received from European scientists. The original cultures of these annual "pepper-grasses" were made in France under glass for a period of years and the progeny of plants so grown were found to have developed a precocity which persisted when seeds were sown in the open field, whereas control cultures never subjected to glasshouse conditions did not exhibit this characteristic of early development. Resulting strains said to have been developed by growing under glass are being tested at Algiers, Marseilles, Rennes and Rothamsted and it seemed desirable to have an additional check from cultures grown in the climate of California. These were carried out at the new station at Stanford University with seeds supplied by Professor Lesage. The results as to precocity are very close to those reported from the other stations. This confirms Professor Lesage's findings as to differences in the cultures, but our work is not designed either to confirm or to deny reported induction of these differences.

A knowledge of the influence of climate upon chemical process in the plant is of high biologic as well as practical value. Arrangements were therefore entered into with Dr. Walter T. Swingle, of the U. S. Department of Agriculture, for the growing at 3 of our stations of some 240 transplants representing 3 alkaloid-producing species of medicinal subshrubs, the resulting differences, if any, to be checked against those from similar plantings made in southern California by Dr. Swingle. During the present year these plants have been set out and charted at the Division's tracts at Stanford University and at Mather, while a reserve set is being held for planting at timber-line station as soon as garden facilities are there completed. These plantings are exact duplicates of one another and of those in southern California, so that differences developing in alkaloid content may be attributed to environmental influence.

In connection with her genetic and taxonomic studies of North American roses, Mrs. Eileen Erlanson, of the University of Michigan, has found it desirable to maintain cultures in California, especially of forms native to this state. A knowledge of the nature of characters involved in classification of the species of *Rosa* is of such fundamental importance that a small area at Stanford University has been set aside for this purpose. Here are now being grown 58 transplants of 7 species selected by Mrs. Erlanson. Divisions of these will be carried into other climates and soils as represented at our mountain stations.

DESERT INVESTIGATIONS

BY FORREST SHREVE

The individual investigations in progress at the Desert Laboratory fall within the rather extended field for which its natural surroundings and laboratory equipment give opportunities of a specific character. The researches which have been carried out at this laboratory during the 25 years of its existence have been chiefly concerned with the desert as an environment and with the physiological and ecological behavior of desert plants. During the quarter century over 50 persons have conducted investigations or pieces of work, from which as a whole there may be drawn some important lines in the picture of the physiological and evolutionary

processes which are operative under arid conditions. With the guidance and orientation afforded by the work of the past, a careful study has been made of the direction in which it seems most fruitful to extend the work of the future, with the aim of devoting an increasing share of the energies of the laboratory to fundamental work in the field for which it presents unique opportunities. Initial steps have been taken toward a closer co-ordination of work on environmental conditions, particularly as related to habitat differences, and on the water relations of soil and plant. Greater attention is being given to certain institutional projects, which are being organized in such a manner that there is assurance of their continuation under changes of personnel. These projects include the study of environmental conditions, the observation of prolonged soil processes, and the measurement of vegetational changes.

Considerable work has been accomplished in the past on the physiology of succulents. The immediate activities of the laboratory contemplate a fuller investigation of some of the non-succulent types, which are more abundant and ubiquitous than the succulents, meet more directly the adverse water conditions, and comprise all of the economic plants of the arid states. The non-succulent shrub *Covillea* is now being used, in whole or in part, as material in investigations of transpiration, of mineral nutrition and of germination behavior.

The development of a coherent program of work on the physiology of desert plants contemplates particular attention to their water relations and the influences of the water content of soil and plant, and looks toward the close correlation of laboratory work with investigations of field conditions and plant behavior under natural conditions.

Changes in Vegetation on the Grounds of the Desert Laboratory

The tract of 840 acres surrounding the Desert Laboratory, and comprising the slopes of Tumamoc Hill, has been given effective protection against grazing and trespassing since 1907. Prior to that year there had been only slight disturbance of the larger perennials, and the twenty-two years of protection have enabled the plant life to return to what is believed to be a condition closely approximating that of the virgin desert. In the most accessible parts of southern Arizona the desert has been considerably modified by over-grazing and by recent activity in homesteading. As a natural preserve the grounds of the laboratory consequently attain a greater value every year.

In recent months a study has been made of the changes which have taken place in the vegetation of the laboratory grounds during the period of protection. Between the years 1906 and 1910 six small areas were selected, exhibiting different types of vegetation, their locations were permanently marked, and accurate maps of their vegetation were made, showing the location of each perennial plant. A larger area was laid out in 1910 on which a census of plants was taken without mapping. A new census and new maps of the areas were made in the fall of 1928 and spring of 1929, making it possible to determine the changes which have taken place during periods of 18 to 23 years.

The areas on level ground, where grazing had been heaviest before 1907, showed an increase in plant population ranging from 33 per cent to 302 per cent. The areas on the slopes of Tumamoc Hill had been very little disturbed before the erection of the laboratory, and the changes in their plant life during the last two decades may be regarded as the normal ones which take place under natural conditions. On two of these areas there had been increases of 5 per cent and 7 per cent, and on one of them a decrease of 16 per cent. In general the numbers of the large perennials have remained the same or have been reduced, while the numbers of the smaller perennials have increased either slightly or very greatly. The data give some evidence on the relative length of life of plants of different types. The dwarf trees, some of the shrubs and the giant cactus are the longest lived. The smaller shrubby perennials, the root perennials and both the arborescent and flat-jointed opuntias are short lived.

During the period of protection, certain parts of the grounds have shown a conspicuous increase in the perennial grasses, particularly *Muhlenbergia porteri* and *Hilaria mutica*. It happens that the grasses have not yet invaded any of the original observational areas and that no exact data are available on their rate of spread and increase of numbers. In September 1928, a new and larger area was mapped in the southwest corner of the grounds, where the grasses appear to be increasing in numbers. Precise data will be secured here to support the observation that perennial grasses are an important part of the vegetation of undisturbed desert.

Up to this time it is not possible to discover any definite or common trend in the changes in the vegetation of these areas. Their continued observation will determine whether such changes are to be detected over longer periods of time, and also the extent to which climatic fluctuations are responsible for changes in the plant population. More precise data can be obtained on the average ages of different species, and a clear picture can be secured of the ceaseless changes in nature, which take place even in a climate which permits only short seasons of vegetative activity.

Habitat Studies on the Grounds of the Desert Laboratory

One of the characteristic features of desert vegetation is the abundance of annuals, small perennials and seedlings of large perennials to be found growing in the shade of the dwarf trees. An instrumental station was established in February 1929, near the west base of Tumamoc Hill with the object of making a comparative study of the physical conditions in the open and under the shade of a large *Parkinsonia* tree, estimated to be over 200 years old. Rainfall and air temperatures are being measured at this station, but these conditions are not significantly unlike in and out of the shaded area. Continuous readings of evaporation and fortnightly determinations of soil moisture have been made. During the unusually dry months from February to June the rate of evaporation has been almost identical in and out of the shaded area, rising from an average daily loss of 41 c.c. from standard spherical atmometers to 152 c.c. during the course of the readings. The close agreement of the sun and shade rates of evaporation shows that insolation is of relatively small importance in deter-

mining water loss from a white atmometer, as compared with humidity and air movement. This conclusion is not, of course, applicable to the water loss of plants in sun and shade.

After the last one of the spring rains, on April 4 the soil moisture in the shade remained higher than that in the sun until May 20, after which it showed a rapid fall to percentages closely like those in the open.

The temperature of the soil is being determined by soil thermographs installed at 3 and 12 inches in the shade and at the same depths in the open. There is a marked difference between the soil temperature conditions in shade and open. In February the maximum at 3 inches was 11° higher in the open, and in June was 17° higher. At 12 inches there has been a rather constant difference of 9° between the sun and shade maxima. In February the minimum at 3 inches was 4° lower in the open, but in June the minimum was nearly the same in shade and open.

One of the objects of this investigation is to secure data for making a comparison of the differentiation of habitat conditions in moist and dry seasons. It has already been found that there is not a great difference between sun and shade conditions in the driest months, except in the temperature of the soil. It remains to be determined how much greater the differentiation of habitats becomes in the moist months.

Growth on Highly Calcareous Soils, by Forrest Shreve and T. D. Mallery

Three series of soil cultures of *Covillea* were begun in the summer of 1927 in order to test the rate of growth in clay, loam and sand, and to determine the influence exerted on growth by different percentages of finely divided calcareous hardpan, or caliche, mixed with the soils. In nature *Covillea* is commonest on soils which are rich in layers and nodules of caliche. The fact that calcium carbonate is the chief constituent of caliche means that its addition to the soil does little to increase its total soluble salts. After 20 months, the cultures were terminated and the dry weight of tops and average ash content ascertained. In each of the soils used there was a progressive increase in dry weight of plants with decrease in the percentage of caliche. The plants in pure caliche and in 90 per cent caliche grew as well, however, as *Covillea* plants of the same size under the usual natural conditions. Using the weight of tops in the cultures with 90 per cent caliche as unity, it was found that the weight of tops in the soils to which no caliche was added were respectively 3 for loam, 9 for sand, and 25 for clay.

Further work is getting under way with relation to the mineral nutrition of *Covillea*, and also with reference to the influence exerted on the purely physical properties of the soil by the poorly soluble salts comprised in caliche.

Meteorological Investigations in the Arid Regions of Southwestern Arizona and Northwestern Sonora, by Godfrey Sykes

The winter season of 1928-29 has proved to be an exceptionally dry one, and following three other winter periods of sub-normal precipitation it has brought about a condition of restricted and arrested growth in the desert vegetation which is very noticeable. Winter annuals have hardly appeared,

and many of even the more resistant species of perennials are showing the effects of the prolonged drought. At the Desert Laboratory precipitation occurred on only nine days during the first six months of the year, and in but four instances in amounts exceeding 0.20 of an inch. The total precipitation for the same period was 1.51 inches.

The marked irregularity in distribution which is characteristic of the scanty rainfall of Southwestern Arizona and Northwestern Sonora has again become evident, even with the slight precipitation of the past winter and spring seasons. The average for the region as a whole has been approximately 1.40 inches, but at several stations there has been no precipitation whatever for periods of six months or more, while at other stations only a few miles away amounts of two inches or more have been recorded. In several cases these readings have reversed the relative figures of former seasons and have thus demonstrated the general suitability of the network of stations selected and maintained for the purpose of obtaining a record of the average meteorological conditions of the region.

Observations on the Delta of the Colorado River, by Godfrey Sykes

The flood waters of the Colorado during the summer of 1928 carried an unusual amount of silt into the delta, and this added materially to the growing fan of sedimentary deposit which surrounds the termination of the definite channel of the river. The summer rise was followed by a prolonged period of low water, with one brief flood which reached a volume of 18,500 second-feet in October, and a second one of about 14,000 second-feet in November. Throughout the winter the river was exceptionally low, averaging not more than 3,750 second-feet during December and January, and for a portion of the time hardly reaching 1,200 second-feet. This figure is below the winter requirements of the Imperial Valley and, as a consequence, the river-bed was entirely dry below the Andrade diversion dam for a period of some weeks. The first spring rise took place about the middle of March, and this was followed by others of slightly greater volume in April and May. A definite beginning of the summer rise took place during the first week in May, and the water gained steadily in volume for about a month. By June 7, 85,000 second-feet were flowing past the Yuma gaging station, and after some minor fluctuations the peak of the high water was reached on June 19, at 91,000 second-feet.

This comparatively moderate summer flow has not been great enough to open the long-expected main channel between the termination of the definite river flow and tidewater, but has merely added to the growing barrier of alluvial material and further stimulated the surrounding zones of obstructive vegetation. Each foot which is added in this manner to the great impounding dam of sedimentary material and vegetation adds to the uncertainty as to the final breaking loose of the river and the manner in which it will eventually obtain a clear passage to tidewater, inasmuch as it carries the possibility of a breach so much farther up stream. A single great flood, especially a winter flood, might break the barrier at any time, but moderate floods, with intervening favorable growing periods, merely serve to delay the change in alignment and add to the uncertainty as to its probable course.

Further Investigations into the Causes of Variations in the Transpiration Rates of Desert Perennials, by Edith B. Shreve

Last year a preliminary report was made on an attempt to find the effect of osmosis on the rate of evaporation of water from a wet membrane. The work was undertaken with a view to obtaining a physical basis for the variations in the transpiration rate of certain desert plants.

The apparatus employed is so constructed that the rate of osmosis through a semi-permeable membrane may be measured separately from one half of the apparatus and the rate of evaporation from a membrane from the other half. The two parts are then connected so that osmosis acts against the water supply to the evaporimeter. The manipulation is accomplished by means of the proper arrangement of stopcocks. Thus far only solutions of cane sugar and membranes of potassium ferrocyanide have been used.

With the particular membranes that were in use and with the size of acting surfaces, the temperature, the humidity and the wind velocity all kept constant, the following qualitative results have appeared many times:

I. When the osmometer is disconnected from the evaporimeter and allowed to get water freely from outside the system:

1. The average rate of osmosis for any given concentration between 0.01M and 0.5M remains constant for at least 24 hours. Individual readings taken close together sometimes vary.
2. The rate of osmosis increases with concentration from 0.01M to 1.0M but not in a simple relation.

II. When the evaporimeter is disconnected from the osmometer and allowed to get water freely from outside the system, the average rate of evaporation remains the same so long as the conditions of the chamber are not changed.

III. When the osmometer and evaporimeter are joined together so that neither can get water from outside the system:

1. If 0.01M to 1.0M cane-sugar solutions are placed successively in the osmometer the rate of entrance of water to the evaporimeter decreases until—
2. At about 0.5M the water moves in neither direction for several hours. Eventually air enters through the evaporating surface.
3. At concentrations above 0.5M the water moves toward the osmometer. At 1.0M the water moves toward the osmometer at almost the rate for that strength.

The above results show that, under the given conditions, an osmotic solution separated from water by a semi-permeable membrane does affect the rate at which water is supplied to another membrane in the same system from which water is evaporating.

When attempts were made to obtain rigorous quantitative results and thereby discover laws, difficulties with the apparatus arose which took much time to correct. The chamber had to be improved so that a temperature constant to 0.05° C. could be held under a greater range of outside air temperature. A better control of humidity was obtained. Most trouble-

some of all was the matter of stopcocks. Eventually the conclusion had to be reached that there are no glass stopcocks on the market that can be ground to fit well enough to prevent water passing around closed cocks when the system is under "suction tension." The cocks may show a correct test many times but the experimenter can never be sure when a leak of this sort will occur between tests. Consequently stopcocks were given up and a new form of apparatus was designed and built.

In the new apparatus small bulbs for mercury have been blown into the tubes at such angles that they take the place of cocks. The entire apparatus can be sealed when osmosis is acting against evaporation. Another improvement was obtained by making the apparatus small enough to be placed on a good balance, thus allowing for the checking of water movement by weighing the water lost. The grids which were designed to keep the membranes from bending were made thicker and stronger.

Only two complete sets of readings have been made with the new apparatus, but these show a marked increase in accuracy.

Delayed Germination of Covillea Seeds, by Ernest H. Runyon

An interesting case of seed dormancy caused by pericarp characters has been found in the case of *Covillea*.¹ Unless removed from the pericarp, less than half of the seeds of this shrub will germinate. The exact nature of the influence of the pericarp has not yet been determined but it is evident that several factors are involved. Cutting the fruitlet² coat, treating with hydrogen peroxide, or with oxygen, breaks the dormancy. This would seem to be a case of the pericarp limiting the oxygen supply to the embryo. It was found, however, that a substance which leaches out from the pericarp, also from the leaves and stems, when used to moisten the absorbent cotton on which the seeds are placed, retards the germination of removed seeds and almost completely inhibits the germination of the seed of intact fruitlets. The effect of the leach water is not due to its slight acidity nor to an osmotic action; its inhibitory effect is removed by adding hydrogen peroxide. It is concluded, therefore, that the dormancy of *Covillea* seeds is not due simply to a pericarp being impermeable to oxygen. Further studies in progress show *Covillea* germination to be very sensitive to environmental influences, and may lead to a better understanding of the distribution of this shrub.

While the natural reproduction of *Covillea* is poor in mature stands of the shrub (although the mature stands are sufficiently open to give ample room for seedlings), on cleared areas, especially where the soil has been in some way disturbed, seedlings are numerous. It is thought that this may be correlated with the presence of a large quantity of the substance which leaches from the plants and inhibits germination in the mature stands, while in disturbed areas it may be gradually washed away or oxidized. A group of eight observational areas has been established at the west base of Tumamoc Hill in a place occupied by a nearly pure stand of *Covillea*.

¹ Studies made at the Hull Botanical Laboratories, University of Chicago, and at the Desert Laboratory, Tucson.

² The fruit of *Covillea* is a hairy schizocarp which at maturity splits into five, single-seeded, achene-like fruitlets.

From four of the areas the plants have been removed and in each of the four the surface has been respectively spaded, raked, covered with a 3-inch layer of soil, or left in the original condition. The other four areas were treated in the same manner, but without removal of the existing bushes. It is anticipated that these observational areas will give further evidence on the conditions controlling germination and survival of *Covillea*.

*Large Variations in the Water Content of Covillea Leaves, by
Ernest H. Runyon*

Studies have been made of the water content of *Covillea* leaves, twigs and larger stems, and of the diurnal and seasonal variations in these. The diurnal change in the water content of leaves containing much water was large—as much as plus or minus 20 per cent; that of leaves of low water content was comparatively small—less than 5 per cent.

The degree to which a plant may suffer a decrease in water content and still maintain life activities is a large factor in determining its adaptability to a dry habitat, *i. e.* its xerophytism. Although non-succulent, the leaves of *Covillea* have been found to undergo very large seasonal changes in their water content. Before the summer rains of 1928, the average moisture content was about 55 per cent of the dry weight; after the rains (by the middle of August) the leaves showed a three to four-fold increase, the water content then being 150 to 200 per cent. On the one hand, unlike the succulents, active cells of which may suffer little reduction of water supply because of extensive water-storage tissue, and on the other, unlike the ephemeral annuals, which, except as seeds live only when their water supply can be high, *Covillea* maintains its leaves and presumably some degree of active metabolism even though the water content of its cells is very greatly reduced. Investigations of physiological activity correlated with changes in the water content of *Covillea* are projected.

Investigations on the Water Balance of Desert Plants, by Eduard Schratz

In spite of the fact that in recent years much attention has been given to the question of the water balance of desert plants we are far from a satisfactory understanding of this problem. This is due in part, at least, to the fact that the problems involved have been attacked largely with ecological methods, the conclusion of which can not be proved by exact physiological laboratory experiment. The exceptionally favorable situation of the Desert Laboratory makes possible the combination of correlated laboratory and field experimentation; thus the treatment of many aspects of the problem of water balance offers the possibility of reaching valuable conclusions based on both these methods. Three principal lines of experimental work are in progress. These are taken up separately as follows:

1. ON THE SUCTION TENSION OF DESERT PLANTS AND ITS REGULATION

Distinct differences in suction tension are found in the different plant types of which the vegetation of arid regions consists. In general one may define three more or less definite groups on the basis of suction tension. The annuals, present only during periods of ample water supply, have suction tensions but little different from those of mesophytic plants. They are

accordingly of little importance in the consideration of the water balance of typical desert plants. The succulents, mainly represented in this region by cacti, are characterised by a very low suction tension value, which under normal conditions lies between 3 and 7 atmospheres. The third group consists of xerophytic perennials, which have a high average value of suction tension.

Particular attention has been given to the question of the degree to which different plants are able to regulate suction tension in relation to their water supply. An example of a seasonal plant is *Fouquieria splendens*, which gave normally a lower suction tension in the night than during the day (14 atmospheres during the day, 9 at night). The suction tension varies with the water content of the plant, the plant reacting with increasing suction tension to the water deficit occurring during the day. The same decrease in suction tension normally occurring during the night may also follow sufficient rainfall during the day.

Changes in suction tension over long periods of time were followed in several cacti—*Opuntia discata*, *O. versicolor*, *Carnegiea gigantea*. In particular, the flat-jointed opuntias show a marked increase in suction tension with increasing water deficit. During times of sufficient water supply the average value was about five atmospheres, while during the dry period this increased to 74 atmospheres. Following a rainfall the plant regulates its suction tension very quickly: thus six days after an effective rain the average values were only about 30 to 40 atmospheres as compared with an average value of 65 atmospheres preceding the rain.

Cacti which permanently have a high water content increase their suction tensions but little even after a long, dry period. *Carnegiea* showed at the height of the dry period a suction tension of only 8 atmospheres compared with a value of about 5 atmospheres during the rainy season. The correlation of suction tension with water content was investigated but the exact relation could not be established. The deviations were very great. Likewise, measurements were made on water content and suction tension in tissues of different ages and of different heights. While no certain differences were found in the flat-jointed opuntias, constant differences were observed in *Carnegiea*, the higher levels showing higher water content and lower suction tension.

2. ON THE WATER INTAKE OF CACTUS TISSUE

The investigations on suction tension are based on the increased, decreased, or constant volume of plant tissues in sugar solutions of different concentrations. For the exact study of this response the tissue of *Opuntia* is favorable. The reaction is analysed readily by means of MacDougal's auxograph. Experiments were made with this instrument which gave insight into the relation of suction tension, water content, amount of water gained or lost by the tissues, and concentration of solution. The curves obtained have not been completely analysed as yet.

3. TRANSPIRATION OF TYPICAL DESERT PLANTS

Investigations are in progress on the transpiration of different desert plants characteristic of this region. Emphasis is being placed on the most

exact measurement possible of transpiration under normal environmental conditions. To this end different methods are being utilized, the comparison of which, it is hoped, will lead to more exact methods than are now available. Two methods are being used in the field: first, measurements of transpiration of whole plants or attached branches in the normal habitat by means of enclosing the plant or branch in a bell jar in which light, temperature and relative humidity are maintained as close as possible to the conditions found outside the bell jar. The water lost through transpiration is absorbed in drying tubes from a steady stream of air, the rate of flow of the air being so regulated that the relative humidity within the bell jar is maintained at the value found outside. The second method used is that of weighing whole plants or removed branches on a chainomatic balance over sufficiently long periods of time. In order to obtain data on physiological regulation of transpiration following removal of branches, the readings are made at two-minute intervals. These investigations are not completed and will be continued during the coming months.

Oxygen Consumption of Planaria in relation to Oxygen Tension,
by R. M. Fraps

Lund (1921) has measured the oxygen consumption of *Planaria agilis* in relation to oxygen tension and finds that at tensions above about one-third saturation with air (*i. e.* an oxygen tension of about 7 volume per cent) the worms consume oxygen at a constant rate. More recently Hyman (unpublished data) has studied the effect of oxygen tension on the oxygen consumption of *Planaria dorotocephala* with results of the same order as Lund's.

The *Planaria* used in the present investigations are an unidentified species closely resembling both *P. agilis* and *P. dorotocephala*. Oxygen consumption has been measured by the manometer method in atmospheres containing from 0.9 to 97 volume per cent oxygen. Large worms only (about 25 mm. in length) have as yet been used over the complete range of oxygen tensions. The results have brought out the following facts: First, that for the material and the conditions given, the rate of oxygen consumption is dependent on oxygen tension below tensions of about 15 volume per cent. Second, the rate of oxygen consumption is relatively high at low tensions, reaching a value of about 30 per cent of the normal rate in atmosphere containing but 0.9 volume per cent oxygen. Third, a slight decrease in the rate of oxygen consumption has been observed in relatively high oxygen tensions; the order of decrease is about 5 per cent for the maximum oxygen tension used—97 volume per cent.

The work on this subject is being continued on the basis of the results already in hand. The material and methods of measurement of oxygen consumption are well suited to a more general consideration of the relation of oxygen tension to rate of oxygen consumption of the same species under varying physiological conditions. A more definite statement of this relationship than is now available is possible and should be obtained on the basis of exact experimental data.

Oxygen Consumption of Sections of Planaria, by R. M. Fraps

Among the questions raised by the Gradient Theory of C. M. Child are those related to the measurement of oxygen consumption at different levels of the same organism. Sufficiently accurate and sensitive methods have not heretofore been utilized in such measurements. The amount of material which one may safely use is limited on the one hand, and on the other the differences between compared levels is small. The modified Warburg manometric method developed at this laboratory is now being used in the determination of gradient differences in several forms of *Planaria* and appears to offer promise that the more general relationships, at least, may be clearly formulated. Data are in hand at this time on the measurement of oxygen consumption of sections only. Similar determinations will be made later on carbon-dioxide production also.

Definite results have been obtained on two aspects of the problem. First, anterior sections (of the anterior zooid only) show a higher rate of oxygen consumption than do sections from lower levels of the same zooid. All sections worked with have been of a standard length of $2\frac{1}{3}$ mm. cut from worms about 16 mm. in length. The average value of the rate of oxygen consumption of the section immediately behind the head region is about 18 per cent greater than is the average value for the third section (i. e. the third piece of $2\frac{1}{3}$ mm. in length). These differences are now under investigation in *Planaria* of different size (which is an index of difference in physiological age), in sections of varying length from individuals of comparable physiological condition, and finally from the standpoint of the reaction of sections to specific chemical agents. These latter experiments are directed toward the elucidation of the manner in which the "normal" gradient differences are maintained, which are inferred to exist from the data of other methods than those employed here. Indifferent narcotics, thyroxin, and protoplasmic poisons are being employed.

The second aspect of the problem which has been analysed is that of rate of oxygen consumption of sections with respect to time following cutting. Section sizes were the same as those of the above experiments and have been taken from worms of 16 to 20 mm. in length. Preliminary experiments with first, second and third sections in a single chamber showed that an initial decrease in the rate of oxygen consumption occurred following sectioning. This initial decrease comes to a close within two hours following cutting. The values given in the table as percentage change show the differential rate of decrement in oxygen consumption of the two sections used in this experiment. *Planaria*: starved stock about 16 mm. in length. Sections: $2\frac{1}{3}$ mm. in length.

The decrease in the rate of oxygen consumption of sections has been followed over long periods of time, using first and third sections only. In the accompanying table are given the results of a 32-hour experiment. Twenty sections were used in each chamber. The manometer readings at the end of the first 2-hour period are taken as the basis from which subsequent decrements in the rate of oxygen consumption are calculated. At the end of each determination the manometer chambers were removed from the mano-

meter bath and solutions were changed; solutions were changed again at the beginning of each test.

Decrease in rate of oxygen consumption of first and third 2½ mm. sections in Planaria sp.

Time following cutting of sections	First Section		Third Section	
	Scale change in mm./hr.	p. ct. change, O ₂ cons.	Scale change in mm./hr.	p. ct. change, O ₂ cons.
2 hrs.	-39.3	.....	-32.7	.....
	-38.8	.....	-33.4	.....
	-39.1	.....	-33.1	.....
	-36.5	- 6.6	-30.0	- 9.1
9 hrs.	-34.2	-12.5	-26.6	-19.4
24 hrs.	-17.4	-17.4	-24.9	-25.9
32 hrs.				

These data clearly bring out the differential response of rate of oxygen consumption of the compared sections, as do all now in hand on changes of rate of oxygen consumption of sections with time. At the end of 32 hours the decrease apparently continues. It has not been practicable thus far to carry experiments over longer periods of time. This will be done later as a part of measurements of rate of oxygen consumption of sections over the entire period of regeneration. Also, the data on time effects will be related to absolute rate of oxygen consumption for all cases.

FURTHER NOTES ON REFINEMENT OF THE MANOMETRIC METHOD

In order to obtain manometric determinations at any time without bringing the chambers to a stop, a manometric unit containing 12 instruments has been designed in which the gages remain stationary at all times, while the chambers are shaken continuously. The chambers are attached to the manometer gages by means of lengths of fine-bore metal tubing, fixed at one end to communicate with the gages. The lower end, containing the chamber, is held in place by the shaking clamp when experiments are being run. The chambers and attached tubes are readily removed; the gages of course remain fixed in the bath at all times. Some difficulty has been experienced in the use of highly sensitive manometer gages through sudden minor fluctuations of the filling solutions due to atmospheric irregularities. These have been eliminated by connecting the pressure tube of all gages to a large vessel closed to the atmosphere. These and other modifications are described in a paper to appear in *Physiological Zoology* at an early date.

ECOLOGY

INVESTIGATIONS UNDER THE DIRECTION OF FREDERIC E. CLEMENTS

AUTECOLOGY

Calorimetry, by Frances Long

The measurement of the total energy involved in plants has been carried on throughout the year, at Carmel, Santa Barbara and the Alpine Laboratory at Pikes Peak. Further improvements have been made in the details of the technique, and a new type of compact portable oven has been constructed for drying materials. A wide range of plants and parts has been employed to test the dependability of the method, but attention has been focused chiefly on variation in leaves of the same plant and individuals of the same species, and the differences between species in the same habitat and between forms of the same species in different habitats. The last two bear directly upon the major problems of the relation between climate and climax and the response of species in their adaptation to effective habitats. Intimately connected with these is the calorimetric study of standard and quadrat phytometers through the climatic and edaphic series of experimental gardens at Pikes Peak and Santa Barbara.

A Parr oxygen bomb-calorimeter has been employed for determining the heat of combustion, and this has been standardized by means of benzoic acid Kahlbaum c.p., specially prepared for calorimetry. The bomb and capsules are made of the alloy illium, resistant to the nitric and sulphuric acids often formed in combustion, but much less expensive than gold or platinum. Rapid drying of plant material at moderate temperatures is essential to accuracy, owing to the effect of respiration or the action of enzymes. This demands an oven with considerable capacity, special ventilation and much uniformity of temperature throughout. In building an oven to meet these requirements, rock wool was placed between double outer walls as an insulator, and a small motor was installed at the back to force a current of air over the heating coils in the base and up through the air-chambers at the sides. At the ends of each shelf, adjustable shutters

TABLE 1—Total energy in seeds of crop and forest species

Species	Calories per gm. dry wt.	Calories per seed	Ash
White durra (Sorghum).....	4017.6	144.6	<i>p. cl.</i> 1.2
Oats (Avena).....	4238.3	143.4	2.5
Wheat (Triticum).....	4282.3	.....	0.8
Scarlet-runner (Phaseolus) ¹	4282.2	.....	.....
Corn (Zea).....	4415.2	.....	1.04
Alfalfa (Medicago).....	5068.9	.....	1.7
Hemp (Cannabis).....	5890.7	122.9	3.1
Yellow mustard (Brassica).....	6049.5	.....	3.6
Sunflower (Helianthus) ¹	6758.2	.....	.....
Castor-bean (Ricinus).....	6834.7	2975.56	2.25
Pinus ponderosa 1.....	5556.3	176.0	1.8
Pinus ponderosa 2.....	5625.0	192.43	2.7
Pinus oontorta murrayana.....	5989.2	26.69	2.7
Pinus lambertiana.....	6480.4	1221.8	1.7
Pinus flexilis.....	7117.7	372.9	2.6
Pseudotsuga taxifolia.....	5998.3	59.98	1.5

¹ Testa removed.

lead from the chambers and in the middle is an opening to the outlet at the top. The drying trays are five in number and 20 by 36 inches in size. The thorough insolation and the freedom of air movement have made it possible to keep all parts of the oven within a range of 2° C.

The plant material is dried at 65° C., ground into a powder and made up into pellets of approximately a gram. One gram of sunflower leaf produces a rise of about 2.7° F.; while the error in reading the temperature is reduced with a larger amount, it is more difficult to control the adiabatic lag. With material containing considerable oil, resin or rubber, smaller amounts are desirable in order to prevent too great a rise in temperature. As a regular procedure, determinations were made in triplicate, but with limited amounts of material, duplicate readings necessarily sufficed.

Seeds have been employed extensively in the preliminary studies, since respiration is at a minimum and the task of drying is also much simpler. Combustion proceeds readily enough when whole seeds are utilized, but better average results were obtained from pellets of ground material, owing to slight variations in the individual seeds. Determinations were also made of the total energy at different stages of seedling growth for *Avena*, *Triticum* and *Zea*, in comparison with that for the seed, indicating that most of the latter was probably used in the process of respiration. The following table gives the results obtained for a number of agricultural crops and forest trees.

Determinations of the total energy of leaves of *Helianthus* yielded consistent results in the several series, the values dropping with much regularity from the topmost to the lowest pair, as shown by the following table:

TABLE 2—Total energy in leaves of *Helianthus*

Leaf pairs	Calories per gm. dry wt.	Calories per sq. cm.	Ash
			<i>p. cl.</i>
Topmost (7th).....	4126.2	20.28	12.7
6th.....	3755.4	8.86	16.7
5th.....	3951.2	9.35	13.4
4th.....	3651.4	8.70	14.6
3d.....	3413.0	7.76	21.8
Lowest (1st and 2d).....	2631.4	6.08	23.2
Topmost (11th).....	4336.8	13.49	11.1
10th.....	4212.1	11.75	10.9
9th.....	4043.2	10.40	13.5
7th.....	3780.5	9.84	15.4
5th.....	3489.3	7.27	17.4

Anthokinetics, by G. W. Goldsmith and A. L. Hafenrichter

The research on the factors and mechanism involved in the opening and closing of flowers has been brought to a close, and the results are nearly ready for publication. The major objective has been to throw light upon the cellular forces concerned in movement, the response being visible and hence readily measurable. Associated necessarily with this have been the determination of the physical factors effective in the process both in the field and under control, and the study of the types of behavior exemplified

in hemeranth, nyctanth, ephemeral bloomers, etc. Nearly one hundred species of the several types have been studied in the field in the light of the instrumental records. Representative ones have been subjected to series of changes in one factor by means of a specially designed ecostat, which permits keeping the other factors at a constant level. Determinations of the tone in the tissue concerned have been made by means of the methods of plasmolysis and tissue tensions. The relation of turgor in plant or flower to movement has been investigated also by measuring floral transpiration and by controlling the water relations of the plant by cutting, irrigation and injection.

Floral movements may be initiated by changes in either temperature or light, or by the simultaneous alteration of both. Humidity is not effective in causing or hastening movement, but it does influence the duration of the open condition in many hemeranth and nyctanth. The water supply of the plant or flower apparently has little concern with movement, except when it approaches the wilting point. Ephemerals exhibit senescence of the tissue before the collapse of the flower; though senescence is not checked by increased humidity, collapse of the tissue is delayed. In general, the sap content of the flower reaches a maximum about the time of opening and a minimum at the closing period. Floral transpiration follows the evaporation from a free water-surface so closely as to indicate that it is cuticular and not stomatal.

A daily rhythm regularly occurs in the hemeranth studied, producing a tendency to open and close at the usual time for plants in the field. This periodic tendency may or may not be effective in causing movement, depending upon the level of the several factors. The threshold of stimulation is lowered when the direction of movement due to a changed factor is the same as that of the periodic tendency, and raised when these are opposed. Under constant conditions, the rhythm becomes weaker and it disappears in some species after 24 hours. It is established and conditioned by the daily cycle of habitat factors; it is disturbed when movement is checked by low temperature and darkness, and the opening and closing movements may then follow stimulation at any time. Light is more effective in establishing periodicity, and temperature in determining the response. Movement is thus partially determined by a preparation period that precedes opening, a fact that must be constantly taken into account.

In the region of maximum movement, the two epiderms are differentially cuticularized, and portions of them can be readily removed with a minimum of injury to the cells. The concentration of the cell-sap was determined by the plasmolytic method and also cryoscopically by means of a freezing chamber adapted to the microscope. A daily cycle of osmotic concentration was found in the epidermal layers, the differential of increasing concentration being in the direction of movement. Although there is considerable difference between species, this relation generally obtains immediately before the opening and closing movements. From the fact that the water-content of such active regions is high at the time of opening, it seems probable that movement is due to hydration changes in the tissues on or near the opposing surfaces of the moving flower part. However, in ephemerals the closing reaction is accompanied by collapse, the senescent condition of the cells appearing soon after the flower expands.

*Experimental Adaptation and Morphogeny, by F. E. Clements
and C. J. Whitfield*

Both adaptation and morphogeny are concerned with the modification of species by the habitat, but the one deals primarily with the direct response to physical factors, the other with the manipulation of the plant in less direct relation to the habitat. In the present series of investigations, the attack upon adaptation is made from two directions, namely, upon this as an ecological process that lies at the base of all physiological and structural change, and upon it as a method of conversion of one form into another. The study of the process itself has been approached from the standpoint of a single controlling factor, such as light, water and nutrients, and from that of such a factor-complex as that of altitude, while competition has served to give a third set of conditions. The gardens and cultures for this purpose have taken a variety of forms, but may readily be grouped as natural and control. The first are centered chiefly at the Alpine Laboratory and are arranged in series based upon light, water and altitude. The second are located at Santa Barbara; they comprise three groups—light, water and nutrients—each with plus, median and minus values. In addition, competition and inversion cultures, light and water transects permitting more or less control as desired are installed at both bases.

In practically all of these, a definite number of individuals has been employed to test the assumption that adaptation is merely selection, and growth and survival have been closely followed, as well as modification. For the three years concerned, the results have been entirely concordant. All species and forms in the various types of culture have exhibited the same general response to the paramount factor. The individuals of each species have taken on a uniform stamp in each habitat or value, or a consistent variation in correspondence with the gradient of a light or water transect. Elimination has been altogether exceptional, outside of the extreme dosages designed to reveal the limit for each species, and there has been no evidence of strains not amenable to the influence of the efficient factor.

One of the most sensitive indexes of adaptation has proved to be the stoma, its number, size and daily cycle furnishing a convenient basis of comparison between the adapted forms. Number in particular appears to follow an almost universal rule, being inversely correlated with growth. For example, *Clarkia elegans* gave a ratio of 2:1.5:1 in sun, half-shade and full-shade and a score of species yielded comparable results in adaptation series, transect and competition culture.

A large number of native and cultivated species have been tested for response to morphogenic manipulation, and approximately a dozen have been selected for intensive study on the basis of their initial promise. Of these, *Plantago lanceolata* has proved to be without a peer, yielding more anomalies or terads, both of kind and number, than all the other species employed. Two wild plants of normal appearance and structure were transplanted into the garden at Santa Barbara in 1925, and others have been moved in from time to time since that date. Chiefly as a result of hypertrophy brought about by optimum conditions, a considerable number of

bracted and of multiple spikes developed the second season. The following year the stamens became abortive in two plants; producing a pistillate form with included staminodes. During the past two years the same form has developed in a half-dozen other cultures, usually with an exact intermediate between it and the normal plant with perfect flowers. A noteworthy terad of the past year is composite in type, each flower being represented by a tiny spike of buds, remaining closed except for an occasional normal flower. In another, the flowers are few and each is borne on a long delicate pedicel resembling a filament. In the case of pistillate terads cloned two years ago, about half the spikes on each plant have become bifurcate or more rarely trifurcate at about the middle.

A striking instance of animal causation has been exemplified by a plant badly infested with slugs, in which the stature is that of a dwarf, the leaves filamentous and chlorotic, and the spikes globose, with but one or two normal flowers. The marked plasticity of this species is perhaps best illustrated in the competition cultures, in which the suppressed individuals are a few inches tall with small leaves and spikes, and the dominant ones 4 to 5 feet high, with leaves 1 to 2 feet long and spikes 4 to 5 inches in length. In spite of the difficulty of securing selfed seed from terads, and especially pistillate ones, the progeny of several is now being grown to determine the fixity of each form, and the cytological behavior of normal and terad forms is also under investigation.

A comprehensive discussion of the objectives, methods and materials involved in this research will appear in the August number of the *Journal of Ecology*.

Cycles in Climate and Vegetation, by F. E. Clements and E. S. Clements

During the past fifteen years extensive studies of the vegetation of North America have been carried out through the agency of motor travel, in connection with intensive research at the several bases, Pikes Peak, Tucson, Santa Barbara and Lincoln. Somewhat more than 175,000 miles have been traversed and all the climaxes have been subjected to repeated scrutiny, with the exception of the tropical. The chief objectives have been the recognition and delimitation of the climaxes, their relation to climate and their successional behavior, the changes wrought by cycles of all sorts, and the recognition of indicator communities and the application of the indicator concept to the problems of agriculture, forestry and grazing. A further purpose has been to provide the necessary ecological basis for regional and state surveys of a more detailed and practical character.

For a number of years particular attention has been given to the changes exhibited by vegetation and their correlation with climatic cycles and the coactions exhibited by man and animals. As the focus of a long series of changes with the sharpest gradient, the desert region of the Southwest has been closely examined, the several transects across it extending from the coast to the interior. The broad ecotone from Canada to the Gulf of Mexico between the grassland and deciduous forest has been traced during the past two years, while the forest climaxes of the East have been crossed from Minnesota to Quebec, southward to Georgia and westward to the grassland of central Texas.

Evidence of climatic cycles has been found in a wide variety of communities through this vast region. Of these the relict community in the form of preclimax and postclimax has been the most eloquent as to the outstanding shifts of climate. Naturally, these are the most numerous in the ecotones between the various climaxes, and consequently they have been sought chiefly on the margins of the Colorado and Mohave Deserts, along the front range of the Rocky Mountains, on the debatable ground between prairie and forest in the Middle West, in the regions of glacial activity around the Great Lakes and along the border of the extreme climatic thrust in the southern states. Furthermore, the three great mountain axes of the continent and the two ocean borders have been the major pathways for north-and-south migrations in mass, along which are strewn the evidences of past changes.¹

In many cases the indications given by preclimax and postclimax relicts must be carefully interpreted in the light of the subclimaxes due more or less directly to man. Superficially, the short-grass plains indicate a recent climatic change toward dryness, in consequence of which the taller grasses have dropped out, but actually they are not evidence of a climatic change but are the product of overgrazing. Similarly, the pine forest of the Atlantic Coast and especially the pine-barrens, while they undoubtedly possess a certain climatic significance, constitute a subclimax due to fire and they can only be properly interpreted in this light. The abundant evidence furnished by the margin of the deciduous forest must be weighed likewise in connection with the many coactions of man, *viz*, lumbering, fire, clearing, grazing, etc.

Further evidence of much value has been supplied by other types of communities, which are the result of climatic changes or indicate potential movement as a consequence. Perhaps the most significant of these is the ecocline, found at its best on mountain slopes and on the walls of canyons and valleys. It is the response to the local climates produced by slope-exposure and in its two opposite expressions represents the outcome of the last climatic shift and the possibilities of the next one. This is on the one hand a more or less complete miniature of the clisere or sequence of climaxes found along a great mountain front, while on the other it is related to the *seriation*. This is the series of communities found from one side of a valley across the valley plain to the other; it is partly a matter of topography and runoff, partly of climatic factors direct in terms of insolation. It represents the potential movement within an association or faciation and serves as the link between the seral and climax communities of a particular region. Finally, the faciation portrays the most recent differentiation of the association in response to climate, just as the associations of a formation represent the earlier climatic modification of the latter. The faciation is the key to understanding the structure and response of all large associations and its recognition has become essential to further advance in the study of climatic communities and their phylogeny.

The most difficult as well as the most attractive task in this field is the comparison of the various kinds of evidence and the correlation of the

¹ Report of the Conferences on Cycles, pages 64 to 70.

changes in the different climaxes. This has advanced to the point where it seems possible to arrange the changes of climate and climaxes on the North American continent in a spiral sequence of cycles, one based upon rainfall with the focus in the Southwest, the other chiefly upon temperature with the center in the Northeast.

Climatic Cycles and Tree-Growth, by A. E. Douglass

The work in this field during the past year has been centered on the long records of *Sequoia gigantea* in the Sierra Nevada. Previous tests have shown that similar climatic records appear in all the sequoia groves as judged by deficient or drought years, but that the northerly groves decrease in sensitiveness to climatic changes by comparison with the southerly ones. The summer of 1928 was devoted to cross-dating the collection of fourteen tree radials secured in 1925. One of these was found to contain 3,000 rings and thus became the fourth known sequoia of that age. The fourteen pieces have been dated and then measured by Mr. P. C. Keenan, using a standard cathetometer, self-checking method involving some 20,000 settings. These measures were entered in tables and are now in process of reduction to develop the best possible curve of sequoia growth.

For proper adaptation to cyclograph analysis, three tables have been compiled in which each tree appears separately. Table I gives the measure for each year; table II the pentade or 5-year sums and table III the 25-year sums. Each tree was then plotted as it appears in tables II and III. The various plots of the 5-year sums as shown in table II were used for comparisons between trees to determine which parts of each form reliable groups and which are best discarded. The small-scale plots of table III were then smoothed as far as possible and their values entered in each table to serve as a standardizing base. In this operation each tree value is divided by the corresponding value of the standardizing base and the quotient is recorded in red ink in a new set of tables. This procedure eliminates age curves and other idiosyncrasies of each tree and places them all at a uniform value so that the variations in each will enter the final averages with equal weight.

The red or standardized tables carry only the best selected portions of the best trees. At each point where tree records begin or end in this table, a specially devised merging process is applied, so that no alteration will be produced in the mean simply because the number of individuals changes. It is hoped that the means so produced will come as near a climatic record as can be derived from one grove.

Investigations of the growth of pine trees over the Sierra Nevada area have shown that nearly the whole range of mountains acts as a climatic unit. Hence, it is probable that the Springville sequoia curve, after being viewed for its own characteristics and compared with the Kings River curve, will be merged with similar ones from the other groves to constitute a general curve for the Sierra Nevada. At the same time it is fully recognized that the sequoia tree record, though obviously climatic, is still in need of extensive tests for its complete interpretation.

*Monographs of the Grassland Climax, by F. E. Clements, J. E. Weaver,
B. C. Tharp and A. G. Vestal*

As the most extensive and highly differentiated of world climaxes, the grassland formation of North America has been the subject of both intensive and extensive ecological investigation for more than thirty years. Its development and structure and its climatic relations are known more fully than for any other climax, and hence supply a detailed pattern for similar studies the world over. It furnishes a graphic record of the major changes of climate, which have been under investigation for the past decade, and the composition and relationships of the several associations have received intensive study by resident investigators for the past five years, in accordance with the plan for an organically related group of four monographs. The main features of these are the structure and behavior of each association in relation to climate, the course of succession in relation to physical factors and community functions, the climatic significance of ecotones and relicts, and the application of the indicator concept to the classification and utilization of land.

The central monograph of the group is devoted to the mixed prairie, which is the modern representative of the original matrix out of which the other five associations and the two subclimaxes have developed. The true prairie and subclimax prairie represent the eastern development of this under a higher rainfall, the coastal prairie and desert plains the southern under a more or less subtropical climate, and the Pacific and Palouse prairies the western in relation to winter precipitation.

True Prairie and Subclimax Prairie, by J. E. Weaver

The field work of the past year has covered much of the area of the two prairies, extending from central Kansas through eastern Nebraska and western Iowa to South Dakota and southwestern Minnesota. An especial search has been made for extensive relict areas as representative of the primitive structure, and the relations of dominants and subdominants have received particular attention. Typical quadrats have been installed in the various areas and the changes incident to annuation and disturbance by man have been traced in detail.

More intensive studies have been made in the high and low prairies about Lincoln, in which experimental analyses of ecesis and competition have extended through the past decade. These have comprised quadrat determinations of composition and aspects, of the various degrees of overgrazing in native pastures, and the rate and nature of recovery after grazing animals are excluded. The presence of preclimax short-grasses and postclimax tall-grasses in an association of mid-grasses furnishes an unusual opportunity for unraveling the changes that have taken place during the historical period.

The most important primary succession is that of the hydrosere, and this has been studied experimentally with the assistance of Dr. Himmel by means of cultures of the four dominants, *Scirpus*, *Typha*, *Phragmites* and *Spartina*, in four different holards from saturation to dry soil.

Coastal Prairie and Desert Plains, by B. C. Tharp

The work of the year has been centered upon the structure, limits and relationships of the coastal prairie, the coastal swamps, both fresh and salt water, and the subclimax forest that succeeds them. The northern and western limits of the first have been followed along the contact with the mixed prairie and the ecotone outlined between them. *Stipa leucotricha* has been employed as the index of the former, and *S. comata* and *pennata* for the latter. The eastern limits of the first dominant have also been determined, falling in the region of the pine-oak forest, where *S. avenacea* likewise occurs. The eastern portion of the prairie differs materially from the western, and it appears probable that two or more faciatisons must be recognized, the easternmost of which is perhaps subclimax.

Through the courtesy of Mr. Paul T. Seashore of the Louisiana Land and Exploration Company, a speed-boat was made available for the investigation of the coastal marshes lying south of the prairie, with the consequence that a large area was covered much more thoroughly than could have been done otherwise. The fresh-water marshes comprise a very large number of dominants, the majority of which constitute a similar associates in the subclimax prairie of the north. The salt marshes consist of *Spartina*, *Sporobolus*, *Fimbristylis* and *Juncus*, and are closely related to similar communities, both east and west. The major dominant of the woodland on the low ridges along bayous and bays is *Quercus virginiana*, associated with other oaks, such as *phellos*, *nigra* and *alba*, with *Celtis*, *Ulmus*, *Acer rubrum*, etc. The presence and growth-form of *Q. virginiana* and *laurifolia* indicate a definite relationship with the forest of peninsular Florida.

Pacific and Palouse Prairies, by A. G. Vestal

Relict areas of the original bunch-grass prairie have been visited throughout much of California, the longest expedition being through the central and southern sections of the state for the purpose of comparing the inland and coastal faciatisons. Especial attention was given to savannah of coastal sagebrush and to the soil preferences of grassland and chaparral, with respect to their climatic relations and the effect of fire upon the two. The exclosures at Palo Alto yielded further evidence of the course of regeneration under protection, *Elymus sitanion* in particular reappearing in marked abundance, in contrast to relict areas naturally protected, where *Stipa* was dominant.

The transition from the Pacific to the Palouse prairie was traced from northern California to Oregon and Washington, and the structure of the latter studied throughout. Outside of the central and typical region, it is generally invaded by the basin sagebrush, which often takes on the semblance of a climax where the grasses have been largely grazed out. The chief dominant, *Agropyrum spicatum*, mixes and alternates with *Stipa comata*, the major species of the mixed prairie, over a wide territory and the two associations are consequently bound together by the broadest of ecotones.

The Phylogeny of Climaxes, by F. E. Clements

An outstanding objective of biology is the natural system. This applies equally to the complex organism, the community, as it does to the simple organism, the genus-species. The century-long endeavor to encompass the natural system of flowering plants has seemed to many to lead but to a mirage, but this has been the consequence of a failure to apply accepted principles consistently, and especially to make experiment a basic method. It seems evident that one can speak only of *the* natural system and that the many systems proposed are natural only in so far as they attain this. Again this applies with full force to climaxes as to genera and for the same essential reason that at bottom they consist of the same units. The evolution of the simple organism has been intrinsic in that of the more complex community; the two processes have gone on together and they have been directed by the same complex of causes.

The view here advanced is that changes in the phase of the major climatic cycles have brought about mass migration of climaxes, with accompanying adaptation and extinction in varying degree and the gradual differentiation of the dominants and the communities formed by them. The life-form has played a decisive rôle between the three fates—migration, adaptation and extinction—and this is reflected in the corresponding climaxes. The herb-form has moved most readily and within a more rigorous climate, with the consequence that the tundra is the most extensive and the least differentiated of all the holarctic climaxes. The grass-form comes next in mobility and the grassland of the northern hemisphere exhibits a striking community of dominants, but to a less degree than the tundra and over a shorter range. The tree-form is much less mobile, and correspondingly subject to either modification or extinction. Relatively few dominants are common to the two continents and this is reflected in the differences between the forest climaxes, both coniferous and deciduous. The animals of a climax are potentially more mobile than the plants, but actually they appear to be less so. Their chief control is food supply rather than climate, and hence their migration is determined primarily by that of the dominant plants, which furnish them food and shelter.

As an epitome of the evolution of the genus and of the community, phylogeny is the immediate basis of the natural system of climaxes, and ontogeny or succession for the reference of developmental communities to the proper climax. However, the phylogenetic method encounters many of the same difficulties that are met in the natural classification of families and orders. Chief of these are a static and subjective viewpoint and the consequent neglect of experiment, but paramount is the obstacle arising from the fact that the units of both systems, the genera and species, are not based upon evolution but upon opinion. This constitutes the greatest hindrance to the phylogenetic study of formations and associations, and one that must be minimized to permit a natural system of climaxes. Fortunately, while the experimental and statistical attack is acquiring momentum, a return to the taxonomic views of a generation ago affords a working solution for the ecologist.

Three approaches are being made simultaneously to the problem of the phylogeny of climaxes. The most concrete has to do with the evolution of

associations, that is, the differentiation of the formation, and is best illustrated by the grassland climax of North America. The unity of this vast formation is based upon a number of criteria, but it rests chiefly upon the presence in practically all the associations of a common group of dominants, viz, *Stipa comata*, *Agropyrum glaucum*, *Koeleria cristata*, *Festuca ovina*, *Poa scabrella*, *Elymus sitanion*, *Sporobolus cryptandrus* and *Bouteloua gracilis*. Because the mixed prairie contains all of these, is central and by far the most extensive, it is regarded as the original association, out of which the others have been evolved. Under climatic compulsion the major dominants have changed in importance, some have vanished in one region and not in another, or have undergone adaptation to form a substitute species, while invaders have crowded in from the margins, notably the *Andropogons* from the Southeast and the short-grasses from the Southwest. The true prairie, desert plains, Pacific prairie and Palouse prairie have evidently each sprung directly from the mixed prairie. The coastal prairie is probably an original offshoot of the true prairie, but the marked invasion of subtropical species and short-grasses has given it an impress all its own.

The second approach is exemplified by the coniferous forests of the continent, which constitute six climaxes and four striking subclimaxes.¹ No coniferous dominant is common to all of these, but the major genera, *Picea*, *Abies*, *Pinus*, range practically throughout in the guise of closely related species. The boreal forest is undoubtedly the original climax from which the others have been derived. Like the mixed prairie, it is by far the most extensive, but it is relatively poor in dominants, owing to the uniform and rigorous climate. Moreover, it lies to the north of all the derived formations, which owe their origin to the southward extension of boreal climates by means of mountain axes and ocean currents.

By far the most difficult approach at present is that to the holarctic climaxes and their phylogenetic relationships. While the general features of this seem clear, the concrete application of methods and principles is difficult, owing to the fact that relatively little of Eurasian vegetation has been analyzed in terms of the climax concept. In spite of this, the enormous amount of floristic and descriptive work furnishes a preliminary basis for sketching in the formations and associations and tracing their general relationship with those of North America.

RESEARCHES IN PALEOBOTANY

BY RALPH W. CHANEY

In the course of the investigation of the fossil floras of western America during the past twelve years, evidence has accumulated to indicate that the Cascade Mountains, which now form the principal climatic barrier in Oregon and Washington, had their origin in late Tertiary time. This range now divides the states into a humid western and a semi-arid eastern province, and the modern vegetation of the two provinces is wholly distinct. The evidence of the fossil floras of middle Tertiary age has shown that no such barrier existed up to the latter part of the Miocene, since the forests of eastern Oregon and Washington were of the mesophytic type now characterizing the Pacific border.

¹ Plant Ecology, pages 421-477. 1929.

Recent studies of the fossil floras of the Ashland, Oregon, region serve to corroborate these biologic indications of the John Day and other fossil floras of the eastern province. Here for the first time have been found Oligocene and Miocene floras on the west side of the Cascade Range which are the equivalents of the well-known fossil floras of eastern Oregon. There is indicated an essential continuity of the forest formations from western into eastern Oregon during middle Tertiary times. But of even more critical importance is the structural occurrence of the formations containing the fossil plants at Ashland. Both the lower flora, corresponding to the Bridge Creek (Upper Oligocene) of the John Day Basin, and the upper flora corresponding to the Mascall (Middle Miocene), together with the intervening Columbia Lava series, are involved in the folding of the Cascade Range, the uppermost plant-bearing shales lying at an elevation of 4,500 feet. The floras are of a lowland type, and the structure of the beds enclosing them indicates that the Range reached its present elevation not earlier than Upper Miocene time. Thus the geologic and biologic evidence unite to indicate that the Cascade Range as now constituted had its origin late in the Tertiary, a conclusion which is in accord with the progressive trend toward aridity which is apparent in the geologic record from the middle Tertiary to the present, in eastern Oregon and Washington.

There is increasing evidence to indicate that at least the northern portion of the Sierra Nevada had its origin at about the same time, and that in middle Tertiary and earlier time forest conditions were comparatively uniform from western into eastern California and Nevada.

Further collections from the Pleistocene deposits on Santa Cruz Island, California, emphasize the close similarity of this fossil flora to the forest now living on the California coast more than 400 miles to the northwest near Fort Bragg. The number of species has been increased from 3 to 8, all but one of which are characteristic of this modern forest of the northern California coast. Many of the problems of distribution of the conifers of western America are closely related to the study of this and other Pleistocene floras, which is being carried on in association with Herbert L. Mason of the University of California.

One of the most striking of the endemic trees of the Pacific Coast is the Sequoia, of which two distinct species are found today, one along the west slopes of the Sierra Nevada, the other in the Coast Ranges of California and southern Oregon. So much of the history of this genus is known, from the Pleistocene of North America and the Tertiary of the Northern Hemisphere that a rather complete story of the course of its present-day isolation may be told. The beauty and grandeur of the living Sequoias, many of which antedate as individuals the rise of modern civilization, make them and their history a subject of more than ordinary interest to those who see them. At the suggestion of President Merriam, and with the cooperation of certain members of the National Park Service who are especially concerned with public education, a number of talks have been given at Yosemite and Sequoia National Parks in which the geologic history of the Sequoia, its present place in the forests of western America, and its future upon the earth have been discussed.

RESEARCHES IN PALEOBOTANY

By G. R. WIELAND

Cycadeoid investigation has come to mean the discovery of a great race of flowering gymnosperms. Not excluding the leaf record, the main study in field and laboratory has concerned the petrified forms of the Mesozoic. The chief objective is to go back through the history of stem, cone and flower. Plant morphologists on the contrary must work forward through the lower types of plants to some conception of the origin of the Paleozoic floras. The primary object of that greatly broadened morphology which concerns itself now with fossils, again with living forms, is of course to better the classifications and chronology and eventually bring to light the history of the now dominant angiosperms.

The celebrated *Raumeria* of the Galician Carpathians has been mentioned in previous reports, the essential features being given. That specimen may be included in the group of well-sectioned cycadeoids. It is one of the most splendidly silicified specimens known, and an adequately illustrated description may now be readily brought to completion. Also, it should be recorded at just this point that the sectioning of such specimens must bring nearer some practical plan by which the greater universities might secure demonstration series of sections (mainly drawn from American material, as the more extensive).

In the case of the American petrified cycadeoids, there is no very visible limit to the amount of laboratory study, preparation and illustration which can be bestowed. The notable accessions of last year from Texas, and from the Navajo country have encouraged renewal of field search for significant finds, now in progress. The staminate flowering of the Navajo series will prove determinable from the newly collected specimens.

A preliminary account of the results of sectioning of the great series of Araucarian and Pinoid cones of the Field Museum collections from the Cerro Cuadrado, Patagonia, has been given (*Science*, Jan. 18). Elaboration of the material being mostly done, with also a considerable part of the illustration, the longer account is well in hand.

Aided by others, a few special studies of Como woods—those of the Cycad-Dinosaur landscapes—are being carried out. Four species of exceptional beauty of conservation are already noted. A description of one of these is shortly to appear. This small group of wide occurrence in the Black and Freeze Out Hills should have had this attention long since. These were the conspicuous conifers of the Dinosaur landscapes. Variation of growth-ring features seen in the different species again raises the question of decipherable climatic indices in such fossils. Subject to further study, the present view is that the stems indicate a fairly wet climate of monsoon type, with a short but sharp winter check, due possibly to some frost. For comparative study of conifer stem structure and seasonal growth, nothing could be finer than these woods.

From the more general or evolutionary viewpoint, cycadeoid study has again reached a turning point where new finds in the field are greatly needed. Further work on the horizons of Rhætic times in both North and South America is a near need. There can be no question that the Liassic

Oolitic section of the Barranca-Consuelo of Southern Mexico as made 20 years ago should get renewed attention. No one should think of upper Triassic-Jurassic plants as either well or adequately studied in this or perhaps any country. Collections may be far more persistently made, and laboratory investigation should be carried out far more intensely. It is strange that no instances of floral structures older than the Rhætic can be pointed out, and unbelievable that fossil flowers of the older Dicot-Monocot lines may never be found, to say nothing of the actual history of cones and of their final relation to flowers.

Nevertheless, the continued examination of the cycadeoids as a great subject in itself is leading to clearer ideas of the older cone and floral morphology, and the possible relation of the later seed plants to the Pteridosperms. At least, the knowledge of the flowering gymnosperms has so increased that actual evidence is now demanded where but a few years ago inference alone seemed possible to attain.

Yet, if the most is to be made of paleontologic evidence, if the points for renewed field work are to be best brought into the foreground, theory must not be forgotten. Except *Wielandiella*, all known older floral structures are, so far as absolute determination goes, gymnospermous. But subtract the petrified record and then see how scant the evidence for the former existence of those cosmopolitan flowering plants would really appear. Absence in the recovered or *seen* record must here be discounted. The greater course of cone and floral evolution beginning in the later Carboniferous and the Permian, and perhaps even marking the dominant types of the Trias and Jura, must yet come into view, must yet be hidden in the coals and lignites.

Until these further sources of material have been tapped, therefore, it may not be known from the indistinct fern and seed contacts of both conifers and angiosperms what the oldest cones and flowers were like, whether their origin was direct, and the great lines of seed plants always discrete, or whether the later lines were related in their early history. The latter view is the one in which, on close analysis and consideration of what is known, the gnetaleans are believed near, and the cycadeoids even nearer those old lines of flowering plants which have come down. If these two groups are so viewed, plant evolution would seem far more varied than the record discloses. Yet there would be unity in the greater course of change. From either viewpoint, however, one very simple item in the course of change is the fact that in the higher seed plants there is visible, from time to time, a tendency for leaf advance to be reflected back into more leafy flowers or fruits, many instances of which could be named. This fact, together with opposed courses of reduction, renders the primitive staminate and carpellate forms difficult to discern.

CYTOLOGICAL INVESTIGATIONS

BY JOHN BELLING

New Method of Staining—The method of staining smear preparations with iron-brazilin has continued to be successfully used. For some time a parallel series of preparations was stained with iron-hematoxylin, but the brazilin slides were superior. Monocotyledons investigated by this method have shown chromomeres at the leptotene or pachytene stages usually in

numbers apparently about equal to those of *Lilium*. This includes species and varieties from 14 genera, namely: *Lilium*, *Aloe*, *Rhæo*, *Tradescantia*, *Brodiaea*, *Galtonia*, *Narcissus*, *Kniphofia*, *Tulipa*, *Hyacinthus*, *Allium*, *Agapanthus*, *Fritillaria* and *Chlorophytum*.

Counting Chromomeres—A method was devised of estimating the number of ultimate chromomeres at the pachytene stage. Counts on favorable material showed that the total number in *Lilium*, *Aloe*, and *Agapanthus* was not far from 2,000. Hence an ultimate chromomere (or rather a chromiole) can be regarded as a gene, with a chromatin envelope.

Nature of the Chromomeres (genes)—At the mid pachytene stage these were paired. Sometimes each member of the pair was seen to consist of two sister chromioles. Often these two sister chromioles were fused, forming a lengthened body. Rarely (as in *Allium*) the two members of the pair seemed both spherical. Sister chromioles seemed always closely connected. Paired chromomeres sometimes showed only a clear space between. Sometimes they were connected by two stained threads. The chromomeres varied greatly in size at the middle of the pachytene stage.

In a small percentage of chromomeres at the pachytene stage there was only one chromomere instead of a pair, and this was on one only of the two conjugated threads. This seemed to be parallel to presence and absence of genes. At the leptotene stage the genes are of different sizes, but have less chromatin. At the late pachytene, chromatin accumulates, and may connect some chromomeres longitudinally. At the diplotene stage it seems as if the members of the pairs of chromomeres, not the sister chromioles, separate.

Contraction of Chromosomes—There seems to be some extension of the threads between the leptotene stage and the mid pachytene in *Lilium*, *Aloe*, *Agapanthus* and *Kniphofia*; but this is not marked in *Hyacinthus* and *Allium*. The contraction of the chromosomes after the diplotene stage is due somewhat to shortening of the filament, and also to zigzags. This corrugation is clearly demonstrable in *Rhæo*, where the homologues are separate. But it can also be traced in *Lilium* and other monocotyledons.

Opening Out of Paired Chromosomes—The writer follows the hypothesis that the opening out at the diplotene stage is between homologues. The alternative hypothesis (Darlington, 1929) appears to be negatived by the work on *Orthoptera*. The writer has shown in *Lilium* that the number of nodes left between the homologues at early diaphase diminishes to somewhat more than half at late diaphase. These remaining nodes are chiasmata. The only available hypothesis for their presence seems to be previous segmental interchange between chromatids of homologues. Occasionally two homologues are also terminally (not sub-terminally) united at diaphase (as they are always in *Datura* and many other plants). In such cases there is no proof of the presence of a chiasma. Deducting such terminal junctions in *Lilium* (all chromosomes) and *Hyacinthus* (4 long chromosomes), the number of chiasmata gives a calculated result not far from the percentage of crossing-over in *Drosophila*.

Constriction Corpuscle—In *Agapanthus*, during most of the pachytene stage, part of each of the 15 bivalents on each side of the constriction is much thickened, while the rest remains thin. In the gap of the constriction

is a round corpuscle, staining yellow with brazilin, while the chromomeres are black. Sometimes two such corpuscles are together. Similar corpuscles have been observed in the thickened parts of the pachytene bivalents in *Kniphofia*, and probably in *Lilium*. If this corpuscle represents the gene for the spindle fiber, etc., it is probably the first gene to be identified.

Triploid Hyacinths—The writer's hypothesis of segmental exchange has been applied to the phenomena observed in the triploid hyacinths, which it readily explains. Another hypothesis advanced for this purpose (Darlington, 1929) is, as already stated negatived by the facts observed in grasshopper bivalents.

High-power Microscope—The new monobromide of naphthalin immersion objective of 1.6 aperture, offered for metallurgy by C. Zeiss, has been adapted for cytological observation by the writer. It gives remarkably clear images, and allows a maximum useful magnification of about 1500.

DEPARTMENT OF TERRESTRIAL MAGNETISM¹

LOUIS A. BAUER, DIRECTOR

JOHN A. FLEMING, ASSISTANT DIRECTOR

GENERAL SUMMARY

The Department has suffered an irreparable loss in the death December 24, 1928, of Dr. Sebastian J. Mauchly, Chief of the Section of Experimental Work in Terrestrial Electricity. Since 1914, he devoted his attention in the Department to problems of terrestrial electricity and the development of instruments and methods for measuring its elements. Among his important contributions is the discovery of the universal 24-hour term in the diurnal variation of the potential gradient of the Earth's electric field, disclosed from discussions of the *Carnegie* results and confirmed by an extensive examination of records obtained at widely distributed land stations. Apart from his scientific attainments, his loss is also keenly felt by his colleagues and friends because of his attitude of helpful service and his charming personality.

The year covered by this report (July 1, 1928, to June 30, 1929) has been marked by excellent progress in the work at sea on the *Carnegie* under the command of Ault. The programs undertaken in magnetism, electricity, oceanography and meteorology have been realized on about 33,000 miles covered so far on the cruise. By means of automatic registration, successfully begun early in August 1928, records suitable for the study of the diurnal variation of atmospheric potential-gradient are being obtained at about tenfold the rate possible with the eye-reading methods used on previous cruises. By the end of the year, records for 110 complete days free from negative potentials had been obtained. Apparatus for continuously recording the conductivity of the air at sea has been completed and tested at Washington and is to be installed on the *Carnegie* at San Francisco in August 1929. Changes looking toward improvements in the study of penetrating radiation both on board the *Carnegie* and on land have been made. The feasibility of further utilizing the cruise of the *Carnegie* in geophysical work has been indicated for gravity-determinations using apparatus of the design of Dr. F. A. Vening Meinesz. The stimulating interest and helpfulness on the part of oceanographical investigators and organizations everywhere has continued unabated.

With the development of Cruise VII of the *Carnegie*, the question of the accuracy of results obtained at sea on this and previous cruises, as well as the problem of finding a method for obtaining the greatest possible precision in the secular change at positions where the courses of the different cruises intersect, became of more immediate interest and have been further studied at length by Fisk. In this study the accelerations of the secular rate, particularly in regions where the rate is large, and the connection between such accelerations and solar activity have also received consideration.

Despite the heavy demands of the *Carnegie's* operations upon the field and office personnel, good progress has been made during the year in the investigatory work along lines reported upon in previous reports including:

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(a) Compilation and study of accumulated data on correlation between solar and terrestrial phenomena; (b) on laws concerned with diurnal, annual, secular and space-distribution changes in terrestrial magnetism and electricity; (c) on measures of magnetic and electric activity; (d) compilation and analysis of the irregular phenomena and disturbances of terrestrial magnetism; (e) determination of suitable corrections to be applied to the results of field-observations for the magnetic elements to eliminate diurnal inequalities; and (f) continued preparation and collection for use of magnetic data for a general review of the rates of secular variation for each of the elements.

The Department has taken part in the rapid development of investigations concerned with radio phenomena, the growing importance of which in geophysical and cosmical research has been so much emphasized by radio-echo retardations recently noted by Norwegian investigators. The diurnal variation in the effective height of the Kennelly-Heaviside layer has been measured. The simultaneous presence of about 30 separate paths for radio waves at night between stations 7 miles apart on a wave-length of 70 meters has been discovered. A new method of studying the Kennelly-Heaviside layer permitting detection of changes of 30 meters in its equivalent height has been worked out.

Satisfactory progress has been made in the high-voltage work. Oil-immersed compact X-ray tubes operating at 1,400,000 volts have been developed. All experimental indications are that the design of these tubes, which is of great flexibility, will permit of extension to much higher voltages.

As the result of Breit's theoretical investigations, anomalies in the magneto-mechanical ratio have been predicted theoretically. The existence of new types of magnetic interactions between electrons not included in the pictures formed heretofore has been derived.

The records of magnetic, atmospheric-electric, earth-current and meteorological elements were practically uninterrupted throughout the year at the Watheroo and Huancayo magnetic observatories, as also the atmospheric-electric work in the Deck-Observatory at Washington. Cooperation with the Apia Observatory was continued with profitable result, and cooperative arrangements were made by which a full program of atmospheric-electric observations will be insured beginning in the new year at the Tucson Observatory (Arizona). The Department has also taken active part in cooperative endeavor with the United States Coast and Geodetic Survey in the plans to establish at the Alaska Agricultural College and School of Mines near Fairbanks (Alaska) a first-order auroral station.

The Department's investigations and methods in earth-resistivity surveys have enlisted further interest. Cooperative field-work was done during the year with the United States Bureau of Mines in three localities. The Imperial Experimental Geophysical Survey of the Council for Scientific and Industrial Research of Australia was supplied upon request with specifications and drawings of this apparatus and method in connection with the investigation of that Council on the application to the location of adequate water-supplies—so vital a matter in many parts of Australia. Some consideration is being given also by the Department to the possibilities of obtaining knowledge of the Earth's crust at great depths by the potential method of exploration.

Every effort was made during the year, as in the past, to effect additional cooperative arrangements with various governmental and other organizations in our fields, and continued marked increase resulted in these activities. This is particularly so for the land magnetic survey, which is the more gratifying as it promises to insure increased accumulation of secular-variation material for which our investigations so greatly emphasize the need in all parts of the Earth to further advance theoretical investigations.

INVESTIGATIONAL AND EXPERIMENTAL WORK

TERRESTRIAL MAGNETISM AND ELECTRICITY AND COSMICAL RELATIONS

Theoretical work has been continued along lines of research indicated in previous reports.

Solar activity and the Earth's magnetic and electric fields—Peters continued his studies by stereographic projection in the analysis and investigation of magnetic disturbances and their relations to solar conditions. Fisk investigated further the lag between solar activity and magnetic activity, his results showing a lag in phase by an amount corresponding to about one-half to three-fourths year, the evidence for which is strongly suggestive. Wallis has under way the comparison of magnetic storms recorded at 18 well-distributed observatories and is studying in particular the modification of world-wide disturbances by local conditions as well as the space-distribution of such disturbances. Fleming, Duvall and Ennis have devoted further attention to the study of really interpretable measures of the Earth's magnetic and electric activities.

Secular variation—Fisk has continued his investigations of secular variation, particularly for eastern Asia, Australia and adjacent ocean-areas with their archipelagos, where the study of the movements of lines of equal annual change is peculiarly facilitated because of the grouping of observatories in China, India and the archipelagos. The contrast between the acceleration-curves found for observatories near the center of rapid change and similar curves for observatories at a distance is significant. These curves for stations remote from centers of rapid change and widely separated from each other bear a close resemblance to sunspot-curves for the same years, that is to say, the accelerations are positive when the number of sunspots is greater than the mean number. The progress of this research emphasizes the great need in all parts of the world of a more intensive program for the determination of secular-variation changes, particularly at much shorter intervals than has heretofore been thought necessary.

Fisk and Duvall have also continued the reduction of accumulated magnetic data to common epoch in anticipation of the further development of the Department's analysis of the Earth's magnetic field.

A promising cooperative investigation with the Department of Meridian Astrometry has been suggested. This relates to Boss's investigation of changes in the rate of rotation of the Earth and the possible correlation therewith of some of the phenomena of terrestrial magnetism and electricity which are dependent upon the Earth's rotation. It seems probable that this cooperative investigation can be advanced through detailed studies of accelerations and retardations in diurnal and secular variations.

Ship-deviations caused by rolling of the ship—The numerical solution of the differential equation derived for a uniform magnetic field of fluctuating strength was carried on by Duvall through some additional cycles, making 25 cycles for each of the three assumed initial conditions. Many more experiments were made by Peters, assisted at times by Green, Wait and Kolar, with various compasses swinging in the cardinal and intercardinal directions under conditions suggested by earlier experiments. These experiments show that compass-deviations depend not only on the azimuth of the vertical plane of motion, the radius of motion, the amplitude of motion, and the periods of ship and compass, but also on some other properties of the compass besides its period and damping. This fact is being studied. The work on the numerical solutions and the results of experiments in general indicate that some empirical method, based partly on theoretical considerations, may be found for obtaining corrections to sea-results in a more simple manner than could be derived from theory alone.

Magnetic charts for polar regions—Peters has continued indexing data in polar regions. The completeness of this compilation has been improved through the collection and publication by Weinberg of Leningrad of all available observations of the magnetic declination made during the period 1556 to 1925 in the territory of the Union of Socialistic Soviet Republics.

RESEARCH ASSOCIATES AND COLLABORATORS

H. U. Sverdrup of the Geophysical Institute of Bergen, Norway, continued as research associate through the year in his advisory capacity in the magnetic, electric and oceanographic programs. He gave some attention to the methods of reduction, compilation and discussion of the observations made in physical oceanography, particularly as regards dynamic effects. Plans were submitted by him for possible cooperative work of the Department in a proposed repetition of the international polar year of 1882–1883 for the year 1932–1933 through an extended program of magnetic, atmospheric-electric, auroral and meteorological determinations at fixed arctic stations.

A. E. Kennelly continued as research associate during the year. He held a conference at the Laboratory in Washington, May 13, 1929, discussing various features of the work being done. He also gave some time to the consideration of arrangements for broadcasting of information upon cosmical physical data (solar disturbances, terrestrial magnetism, earth-currents, aurora, radio reception-conditions and radio atmospheric disturbances). In view of the increasing importance of such data, particularly as regards radio and meteorological conditions, it is hoped that arrangements for such transmissions may soon be realized by a specially appointed committee and placed upon a basis similar to that in effect for meteorological and seismological data. He has also effected cooperation in connection with the experimental work and researches on the height of the Kennelly-Heaviside layer.

C. H. Dwight, assistant to S. J. M. Allen of the University of Cincinnati, made further progress in the study of atmospheric potential-gradient and submitted a report upon some results obtained last summer at a station near Martha's Vineyard. The results obtained were discussed by him at the

Laboratory in Washington in June, and he plans to obtain additional observations at his last year's station during the coming summer.

The importance of the valuable contributions on correlations of radio transmission with solar, magnetic, electric and meteorological conditions by research associate Greenleaf W. Pickard, who continued in that capacity throughout the year, has been emphasized by the developments in the radio-telegraphic field since the last report. Pickard's work has further enlisted cooperative effort and observation. The measurements of night field from station WBBM of Chicago, started in February 1926, have been continued without break at the Harvard Astronomical Laboratory (Cambridge, Massachusetts), under the direction of Harlan T. Stetson. The night-reception measurements from San Francisco to Pasadena, started July 1927, have been continued by Howell C. Brown of Pasadena, California, without interruption. As a result, there is now available a substantially homogeneous body of night-field values extending over nearly three and a half years from Chicago to Massachusetts, and nearly two years from San Francisco to Pasadena. A continuous 24-hour record, begun in June 1928, has also been made at Newton Centre, Massachusetts, from the low-frequency (18.4 kilocycles) station WCI at Tuckerton, New Jersey, in cooperation with L. W. Austin and the Bureau of Standards Laboratory for Special Transmission Research at Washington.

The correlation of these reception-measurements with solar activity, terrestrial magnetism and meteorological elements has been continued and extended. In addition to the relations already found with sunspots, magnetism and air-temperature, the data now at hand have established a prominent 15-month period in the Chicago to Massachusetts reception-series, which closely parallels in inverse relation an equally well-marked 15-month period in the Wolfer provisional sunspot-numbers. A similar 15-month period is now beginning to show in series from San Francisco to Pasadena, but here the cycle is apparently out of phase with sunspots by about four months and is, in addition, directly instead of inversely related to solar activity.

The low-frequency records from WCI are now being studied in an attempt to obtain the height of the lower boundary of the Kennelly-Heaviside layer. A preliminary estimate based upon the sharply-defined sunrise-disturbance common to these records indicates a height of between 60 and 100 kilometers, which is in fair agreement with the theoretical height for this frequency. Brown of Pasadena is now examining, with the aid of Mount Wilson Observatory, the relation between radio reception and indices of solar activity other than sunspots.

In its researches of the Kennelly-Heaviside layer, the Department has also found many interested collaborators who are making records of signal-schedules so generously and specially arranged through the Naval Research Laboratory of the United States Navy at Bellevue, D. C., and who are engaged in independent discussions. Among these are A. H. Taylor of the Naval Research Laboratory, G. W. Kenrick of the University of Pennsylvania, W. Wilson of the Bell Telephone Laboratories, J. C. Swanson of Duke University, L. W. Austin and T. Parkinson of the Bureau of Standards, P. A. de Mars of Tufts College, E. Merritt of Cornell University, and

H. W. Kline of the General Engineering Laboratory of the General Electric Company. Professor E. V. Appleton of the Wheatstone Laboratory, Kings College, England, has offered helpful, constructive suggestions in the progress of the researches.

MAGNETISM AND ATOMIC PHYSICS

Breit, Tuve, Gaviola, Hafstad and Dahl have continued the experimental and theoretical work in atomic physics. The results of the year's work are summarized accordingly.

EXPERIMENTAL

High potentials—The method of producing high potentials which has been previously developed has now been used in trials of constructing X-ray and cathode-ray tubes suitable for operation at potentials of the order of 1,400,000 volts and higher. In connection with the development of tubes an induction and a vacuum baking-out furnace have been constructed. The effect of the conductivity of the glass has been investigated. It has been found that punctures occur only in portions of the glass having a low conductivity. Trials with hot glass electrodes rather than metal electrodes have been made. No essential difference between the two kinds has been found.

A marked improvement on the cascade-method of Coolidge has been made. The size of the bulbs has been appreciably decreased by immersing the whole tube in oil. It is now possible, for example, to have reliable operation at 850,000 volts with a tube 32 inches long made of 100 c.c. flasks. This is a much more compact arrangement than has been used heretofore.

The upper atmosphere—The method of studying the Kennelly-Heaviside layer by means of echoes has been used to study diurnal variations of the effective height. Taking the first reflection to be an indication of the height, it is concluded that the layer rises from the daytime value of 230 km. to over 400 km. at midnight. These numbers refer to effective heights at 70 meters and are representative of a fall and winter condition. Seasonal variations have been noted. The true heights may be much lower corresponding to a daytime value of 100 km. The reflections at night proved to be much more complex than during the day. Their multiplicity at midnight may be as high as ten. In addition, each reflection is broad. Its width has been ascertained to be due to the superposition of a large number of echoes. The layer behaves, therefore, somewhat as a wavy surface with a large number of reflecting facets.

A further development in the method has been made. The phase of the echoes has been compared with the phase of the emitted wave by means of the crystal used in the transmitter. The method is called the echo-interference method because the determination of the phase of the sky-wave is made by observing the effect of interference of the echoes with the constantly oscillating crystal-control.

The importance of this method is twofold. In the first place, it is more sensitive than the previously developed "echo-retardation" method and is for this reason more suitable for the observation of correlations between the fluctuations in the upper atmosphere and small variations in the magnetic

elements. Secondly, the numbers obtained for changes in the equivalent heights for interference are known from theory to depend on the $\int \mu ds =$ optical path, while the effective heights for interference echo-retardation depend on $c \int (ds/V) \cong \int (ds/\mu)$, where V is the group-velocity, μ the refractive index, ds an element of length along the path traversed by the radio wave, and c the velocity of light. Simultaneous observations by the two methods give, therefore, two different effects which depend in different ways on the electron- and ion-distribution in the upper atmosphere. As a result, one may draw conclusions as to the degree of penetration of the rays into the ionized regions.

The above explanation is intended for the reader familiar with the technical side of the subject. For those who are not, a description of the difficulty of drawing conclusions about the upper atmosphere and of the desirability of developing different methods by means of an analogy may be given. Suppose it is wished to determine how far up a slope an automobile has traveled, basing a judgment entirely by observations made before and after the trip. The immediate impulse is to try to draw conclusions from the speedometer mileage-reading. It is impossible, however, to determine the height reached from this alone. The grade must also be known. The echo-retardation method gives the mileage reading. The interference-observations give the indication of the gasoline gage which combined with the speedometer permit drawing a conclusion as to the height reached because more gasoline is used to draw a car up a steep grade than on level ground.

Correlations between the magnetic storms and the reception of 8,000 kilocycles at a distance of 7 miles have been noted. During magnetically quiet periods this frequency is not received over the short distance. In exceptional cases connected with magnetic storms good reception has been observed.

THEORETICAL

The meaning of the principle of uncertainty in Weyl's way of stating quantum mechanics was elucidated by Breit. Calculations on the magnetic moment of the electron were made. The value of the magneto-mechanical ratio was shown to depend on the charge of the nucleus. Thus the Bohr magneton is according to present-day theory not the only possible magnetic moment of the electron. These calculations are of interest in connection with the experiments of Barnett performed at this Laboratory several years ago and explain qualitatively the nature of his results.

The nature of the magnetic forces between electrons was investigated and new kinds of interactions have been found by Breit, as a consequence of trying to satisfy simultaneously the requirements of quantum mechanics, electro-dynamics and relativity. The picture of electrons as point-charges and magnetic doublets has been shown to be incomplete since the new interactions can not be derived from the above simple picture. This work was stimulated by collaboration with Pauli of Zürich and Heisenberg of Leipzig by sending Breit first for four months (September to January) abroad to work with Pauli and then during the month of June to Chicago to be with Heisenberg.

From a consideration of previous experiments, Gaviola drew the conclusion that the statistical interpretation of quantum theory rather than that which had been advocated by Schroedinger is correct. By a careful consideration of experiments on time-lags, he found that the interpretations of these experiments were in most cases incorrect, that the times dealt with were always longer than stated, and that the experiments on cutting light quanta by Lawrence and Beams had been misinterpreted.

Abstracts of both experimental and theoretical researches, published or under way, will be found in the section of this report giving abstracts of publications and investigations (pp. 250, 257, 262, and 267).

EXPERIMENTAL WORK IN TERRESTRIAL ELECTRICITY¹

The work of this section comprises atmospheric electricity, earth-currents, earth-resistivity and other associated subjects, as, for example, the condensation nuclei of the air. It includes the appraisal and central control of the work in terrestrial electricity on the *Carnegie* and at the observatories, the operation of an atmospheric-electric observatory on the deck of the Laboratory at Washington, modification and development of apparatus and methods for measuring the elements of terrestrial electricity, and analytical and experimental investigations. Among other miscellaneous activities may be mentioned the outfitting of expeditions which cooperate with the Department in investigations of this subject. The personnel engaged in this section for the year were Gish, Wait, Rooney and Sherman.

Atmospheric-electricity—Preliminary to the final adjustment of the atmospheric-electric data from the Watheroo Observatory, a critical study of the constants was made by Wait and Gish. In this it was found that the conductivity scale-value was, to a small extent, dependent upon temperature or possibly humidity but more likely the former. This effect can not affect the average values but may introduce a small uncorrected diurnal-variation with a range amounting to about 5 per cent of the mean of day (see p. 273). The atmospheric-electric data received from the *Carnegie* have been studied by Gish and Wait with the immediate purpose of ascertaining the reliability of these data, especially those obtained with new or modified methods, and with a view toward effecting improvements. For purposes of comparison, some of these studies also covered the data obtained on previous cruises (see p. 217).

In order to ascertain more definitely the reliability, at all times of day and during unfavorable seasons, of the insulation of the potential-gradient measuring systems, analyses of data from the *Carnegie* and observatories were made by Wait and theoretical and experimental studies by Gish and Sherman. The former investigation indicates that in seasons when insulation is most difficult to maintain the diurnal variation at the observatories may be falsified by variations in the insulation-resistance. These conclusions have not as yet been substantiated by the latter investigations. Potential registrations on the *Carnegie* show as yet no evidence of being vitiated by defective insulation.

The registration of air-potentials and of negative conductivity in the experimental observatory on the deck of the Laboratory at Washington was

¹ From the report of O. H. Gish, chief of section.

continued during the year chiefly under the attention of Sherman. Factors for reducing the recorded potentials to the gradient over a plain were determined on six occasions by Wait, Sherman, Davies and Gebhardt. These factors show a tendency towards a steady increase during the last two years (see p. 261). This increase may be due to the growth of trees near the Laboratory. The values of negative conductivity recorded at this station are considerably less than values found elsewhere. The cause of this was sought in instrumental factors, but various tests made during the past year seem to exclude this possibility. Calibration with an entirely different method checked the calibration-method normally in use, and measurements made near the recorder with a portable Gerdien apparatus gave values differing inappreciably from those derived from the registrations.

Equipment for recording conductivity on the *Carnegie*, planned by Wait and Gish and designed in detail by Huff, was constructed in the instrument-shop, and was tested and operated satisfactorily for two weeks by Gish in the Deck-Observatory. The steady deflection-method used at the Department observatories is employed (see p. 275).

An assembly planned by Gish and Wait for recording the space-charge of the atmosphere was set up in a shelter on the grounds at Washington by Sherman and continued in operation with some interruptions for somewhat over a month. This work is to be resumed when a more satisfactory air-turbine can be obtained. An abstract of the preliminary results is given on page 261.

A potential multiplier, designed by Gish for maintaining a high potential on the foil upon which is collected the radioactive material from the air in studies of this material at sea, was constructed in the instrument-shop. Tests indicate that this device will maintain a potential of between 4,000 and 5,000 volts on the apparatus without much attention to the insulation. A brief description of this device is given on page 259.

A method of using a bifilar electrometer, together with a guard-ring, so as to eliminate the loss of charge across the insulators of the electrostatic system was devised by Gish and Sherman and tested by the latter, especially in connection with measurements of air-potentials (see p. 260).

A partial analysis of the data registered in the Deck-Observatory at Washington for potential gradient since February 1917 and for conductivity since January 1919, made by Gish and Sherman, showed annual and secular variations qualitatively very similar to most land stations. Owing to the tentative and experimental nature of this observatory in the earlier years and partly in view of the fact that atmospheric pollution and unfavorable exposure doubtless affected these elements here, some of the control-observations are scarce. Further study is needed to ascertain the reliability of the quantitative values (see p. 261).

Fourier analyses of the diurnal variation in the air-potential registered on the *Carnegie* during Cruise VII were made by Wait. These show excellent qualitative agreement with results obtained on previous cruises. On account of some changes from time to time in the exposure of the collector, a quantitative comparison of the gradients is more tedious and has not yet been completed.

Earth-currents—The Watheroo earth-current data from 1924 to date have been studied by Gish and Rooney as regards their reliability, sources of error and relationships to other geophysical phenomena, especially terrestrial magnetism; the results of these studies are given in brief on page 276. The new system of electrodes at Watheroo continued to give diurnal variations from the independent lines in a given direction which were self-consistent. The contact-potential between the extreme electrodes of the east-west line becomes so great during about a month that the value is beyond the working range of the recorder. With the hope of correcting this, the most easterly electrode is to be moved a short distance to a point where the soil is of more nearly the same character as that at the electrode of reference. The earth-current data from the Huancayo Observatory for the year 1927 were analyzed by Rooney and Gish, especially in connection with the planning of an earth-resistivity survey at that Observatory (see p. 260). The study of relations between earth-currents and magnetic storms has been continued as opportunity arose.

Earth-resistivity—Through a cooperative arrangement between the United States Bureau of Mines and the Department, resistivity-surveys were made under the immediate supervision of Rooney in three different mineralized areas. (For abstract of the reports on this work, see p. 266.) Complete working drawings of the special features of the earth-resistivity meter were made by Huff, and blue-prints of these were sent to a number of interested parties. The number of requests for full information regarding this apparatus has been notably greater than in previous years.

Plans for an earth-resistivity survey in connection with the earth-current studies at the Huancayo Magnetic Observatory were prepared, and Rooney left May 7, 1929, for Peru to carry out this work.

Miscellaneous—The Byrd Antarctic Expedition was outfitted with equipment for recording air-potentials, and Observer Davies of the Expedition's staff in charge of this work was instructed in the technique of such work. Information was supplied by conferences and by corresponding with a considerable number of workers in the field of geophysics having problems allied rather closely to some branch of terrestrial electricity. Gish was appointed electrical engineer in the United States Bureau of Mines for consultation in geophysical methods. In August 1928 he was invited by the Michigan College of Mining and Technology to visit Iron River and Houghton, Michigan, to inspect and consult regarding geophysical work under way there. He was also designated consulting physicist with the United States Public Health Service and a member of the Committee on Radium Poisoning in the Luminous Watch Dial Industry. Rooney was appointed electrical engineer in the Bureau of Mines for consultation in geophysical methods. Wait carried out experiments to ascertain the specific cause of fog-formation on the counting-stage of the Aitken nuclei-counter and to find methods of eliminating this effect. Sherman prepared numerous quartz-electrometer elements for use at the observatories of the Department, on the *Carnegie*, and for supplying such cooperating investigations in atmospheric-electric work as the Byrd Antarctic Expedition and the Manila Observatory of the Philippine Weather Bureau.

FIELD WORK AND REDUCTIONS

IMPROVEMENTS AND COOPERATION FOR FIELD AND OBSERVATORY

The maintenance of the instrumental equipment and development of new equipment (see pp. 217, 275) for the *Carnegie* made heavy demands on the staff both on board the ship and at the Laboratory in Washington. Some progress was made by Soule on development of electromagnetic methods in the observations on board (see p. 225). A photographically recording conductivity-apparatus was devised, designed and constructed in the instrument-shop, and it is expected that its installation in San Francisco will permit putting the conductivity work on a par with the potential-gradient work, now being so successfully carried on, for the balance of the cruise.

The necessary supervision and the beginning of the office revisions of the great amount of data and many compilations being received from the *Carnegie* are being looked after at Washington by Fleming, Peters, Wait and Ennis. The last-named was given charge of the physical oceanographic work and has effectively developed means by which labor in the original computations is much reduced by prepared tables. The preliminary manuscripts submitted by Ault and other members of the staff on board were prepared for publication at the office by Fleming and Harradon, and a number have already been published and others are in the press; abstracts summarizing them are given on pages 248-250. Wait kept a close check on the behavior of the atmospheric-electric instruments aboard the *Carnegie* by scrutinizing promptly all the records and computations as they are received.

The experience of Meinesz, Wright and Collins in the gravity-survey executed on the U. S. Submarine S-21 through cooperation of the Navy, the Geophysical Laboratory, Dr. Meinesz and the Institution during October and November 1928 indicated that this type of apparatus could be successfully used even when the roll of the ship was as great as 8° and probably as much as 10° using a gimbal-support permitting sufficient freedom of motion for the apparatus. Upon recommendation of Meinesz and Wright after conference with Bowie of the United States Coast and Geodetic Survey and Day of the Geophysical Laboratory, arrangements were made by the Institution to purchase a Meinesz gravity-apparatus for installation on the *Carnegie* at San Francisco.

The apparatus in which pendulums in pairs are used to eliminate the effects of horizontal accelerations of the ship's rolling motion on gravity-determinations was delivered in Washington, May 24, from the Nederlandsch Seinstoestellen Fabriek of Hilversum, Holland. This delivery could not have been possible had it not been for the courtesy of Director Nörlund of the Geodetic Service of Denmark, who authorized sending an instrument which had just been completed for his Service, and of the loan by Netherlands Geodetic Commission of three standardized invar pendulums. With the cordial assistance of the United States Coast and Geodetic Survey, the Survey's gravity-station in the basement was occupied for the standardization. The apparatus was assembled, adjusted and operated by F. E. Wright (Geophysical Laboratory), with some assistance from Swick, Brown and Pfau (Coast and Geodetic Survey) and Peters. The Navy cooperated by lending three specially rated break-circuit chronometers for the cruise.

A method of recording wireless signals also upon the photographic paper was suggested by Wright and the necessary equipment was assembled in the Department shop according to plans and specifications drawn by Brown of the Coast and Geodetic Survey. After standardizing experiments which were concluded on June 17, the apparatus was repacked and forwarded to the *Carnegie* for installation in August at San Francisco.

COOPERATION WITH OTHER ORGANIZATIONS

The cooperative program with the Mount Wilson Observatory was continued. The plans for an atmospheric-electric installation at the Tucson Magnetic Observatory in cooperation with the United States Coast and Geodetic Survey have been realized and arrangements made by which instruments of Department design and construction will be installed in September, thus insuring beginning of regular records in October 1929.

Acting with the United States Coast and Geodetic Survey, the establishment of a first-order auroral station at the Alaska Agricultural College and School of Mines near Fairbanks, Alaska—a site admirably located for such work—was discussed with President Bunnell of the College during a visit in Washington and plans were made which it is hoped may make possible the development of the work, already being done there by the Department of Physics, comparable with that done by Stoermer and his colleagues at the observatory in Norway.

The cooperative field-program on the application of geophysical methods to determine geological formations with the Bureau of Mines of the United States Department of Commerce was carried out during the year; brief abstract on this work is given on page 218, 266. Numerous requests for accumulated magnetic and electric data continue to be received from all parts of the world; economic applications in the determination of underground structures have been the basis of much of this correspondence.

The plans for both magnetic and electric work at an observatory base-station and on sledge-trips were completed for the cooperation with the Byrd Antarctic Expedition. Two observers of the Expedition's staff were instructed in the use of the apparatus and the equipment was assembled and forwarded. Radio advices indicate that the work has been carried on effectively during the winter at Little America, the base-station of the Expedition, Davies being observer-in-charge with assistance from Gould, the second in command of the Expedition.

The cooperation with the University of Cape Town for magnetic work in the southern part of Africa was continued (see p. 231). Preliminary arrangements were completed to cooperate with the Meteorological Service of British East Africa through the loan of equipment in obtaining magnetic observations at the five East African colonies—a region in which secular-variation data are sorely needed; it is expected that this work will be begun by the end of the calendar year. The disaster to the *Italia* of Nobile's Arctic Expedition prevented realizing the plans to obtain much magnetic data on that Expedition; many electric data, however, were obtained and the manuscript by F. Běhounek, discussing these, is now in the press.

The cooperation of the many organizations listed on page 216 of last year's report in the work of the *Carnegie* has been generously continued

throughout the year. C. F. Brooks of Clark University acted in an advisory capacity on the meteorological program and particularly upon the preparation of plans for the ultimate compilation and reduction of the numerous data and records being obtained on board.

Much consideration was given to study of the future work at sea, particularly in the Pacific Ocean; the Department cooperated with the International Committee on Oceanography of the Pacific and the Oceanographic Committee of the National Academy of Sciences in this.

OCEAN WORK¹

PROGRESS-REPORT CRUISE VII, JULY 1928 TO JUNE 1929

The following is extracted from Captain Ault's report on the progress made during the *Carnegie's* seventh cruise in the year ending June 30, 1929.

The *Carnegie* left Hamburg, Germany, July 7, 1928. The Shetland Islands were sighted July 11 and the Faroes July 12, the vessel passing to the north of both groups.

Prevailing southwest winds prevented making the southward loop as planned between Iceland and the Faroes, so the vessel stood off to the northwest to cross the 1914 track July 14 near the southeast corner of Iceland. Six days of head-winds made it necessary to use the engine for a total of 76 hours; without it Reykjavik could not have been made and it would have been necessary to proceed to St. Johns, Newfoundland, omitting Iceland. Despite bad weather and poor visibility, good series of declination observations were obtained. Only two ocean-stations were occupied, owing to strong winds and time required in tacking against head-winds.

Reykjavik anchorage was reached July 20 in the midst of rain squalls and low-hanging mist and fog. At Reykjavik the 1915 magnetic station on Engey Island was occupied, simultaneous ship and shore potential-gradient observations were made, and bird specimens for the Smithsonian Institution were collected. The vessel left Reykjavik on July 27.

Heading down toward Cape Farewell, good progress was made until July 31, when the winds became unfavorable. By August 3 the wind had sprung up from the northeast and, when opposite Cape Farewell, the course was shaped toward Newfoundland, omitting the loop toward Baffin Bay in order to gain on the schedule.

The aurora was seen during the nights of August 3, 4, 5 and 6. High arches extended entirely across the sky, with some streamers but very little color. On August 5 an iceberg was sighted at a distance of 10 miles and course was changed to pass near; it was 400 feet long and 95 feet high. An ocean-station on the edge of the Great Bank of Newfoundland with 130 meters of water was occupied August 7. The temperature of the water at a depth of 52 meters was $-1^{\circ}6$ C, being $11^{\circ}4$ C at the surface.

During the remainder of the way to Barbados good weather was generally encountered and the regular programs of magnetic, electric and oceanographic work were carried out. The new boom-walk was tried out, and dip- and tow-nets were used from it to good advantage. Various bottom-samplers were tried out under favorable conditions, but two were lost because of faulty wire. On August 31 in latitude 8° north on account of delays through calms, course was changed for Barbados, which was reached September 17, three days behind schedule.

During the cruise from Reykjavik to Barbados the observations included 76 declinations, 25 inclinations, 25 horizontal intensities, 22 ocean-stations, 205 sonic depths, 20 complete and 14 incomplete potential-gradient diurnal-

¹ From the report of the chief of section and commander of the *Carnegie*, J. P. Ault.

variation series, and 10 evaporation-series. Temperature, salinity, density, specific volume, hydrogen-ion concentration and phosphate-content variations from the surface generally to a depth of 2,000 meters and a maximum of 5,500 meters were determined. Plankton-tows were made at surface, 60, and 120 meters with silk tow-nets, and the Petersson plankton-pump was operated at the same depths, at all the ocean-stations. Especially valuable will be the hydrographic section, practically through the center of the North Atlantic from latitude 46° to 8° north. At Barbados the department's magnetic station was reoccupied and deflector No. 5 standardized.

The vessel left Barbados October 1 bound for Colon. En route a fine view of Martinique, scene of the disastrous earthquake of 1904, was had, Mont Pelée showing up clearly except for a cloud bank at its top. Fine weather with occasional squalls with heavy rain, lightning and thunder accompanied the ship until near Colon which was reached October 11 at 11 o'clock, and Balboa at 7 p.m. on the same day.

On this passage the regular program was maintained. Four ocean-stations, 15 declination-, five inclination- and horizontal-intensity stations, and 29 sonic-depth stations were occupied. At one ocean-station owing to an unavoidable accident 4,000 meters of wire and the oceanographic apparatus attached thereto were lost. No complete atmospheric-electric run was made because of rainy weather and leaky ion-counter; 4 complete and 5 incomplete potential-gradient electrograms were obtained. Radio contact with IMK was maintained as usual, and NKF was overheard on several nights working the Byrd Expedition vessels.

After undergoing some minor repairs the *Carnegie* left Balboa on October 25. After 24 hours of fair wind, about two weeks of head-winds, heavy rains, and squally weather were encountered, and it was necessary to tack back and forth and run the engine in order to get away from the Gulf of Panama. It was found necessary to change the route and go south of the Galapagos Islands, instead of north. On the tack to the north and again on the long tack to the southward, Malpelo Island, an isolated, barren rock one mile long and 864 feet high was passed. The rainfall was exceptionally heavy. It was necessary to operate the engine so long before clearing the coast and getting a favorable change of wind that the supply of gasoline was nearly exhausted.

The delay in the Gulf of Panama gave a splendid opportunity for securing a number of ocean-stations in this interesting region. Salinities of surface-water were very low owing to the enormous supply of fresh water poured out by the rivers emptying into the Gulf and from the heavy rain-falls.

While occupying the ocean-station on November 3 the oscillator used with the sonic depth-finder to measure depth failed to operate owing to some short-circuit in the coils. This was a great handicap, since now it became necessary to send the bottom-sampler down on the piano wire first in order to determine the depth before lowering the water-bottles and thermometers. About 100 miles west of the coast of Ecuador at latitude $1^{\circ} 32'$ south and longitude $82^{\circ} 16'$ west, the water-bottles and thermometers were being sent down to the charted depth of 3,000 meters. After 1,600 meters had been lowered and another water-bottle was being attached, the chief engineer at the winch-controls stated that he believed the wire had touched bottom since the reel had slowed down very definitely. Upon hauling the wire and bottles up, ten meters of wire were found to be tangled around the bottom bottle and lead weights, giving a depth of 1,515 meters. A bottom-

sampler was immediately sent down on the piano wire, getting bottom at 1,454 meters and bringing up a small sample of black rock fragments and some globigerina ooze. The snapper had struck hard bottom and closed, but had snapped up only a small amount of material. This new mountain ridge was named the "Carnegie Ridge." It rises about 1,800 meters above the general level of the ocean-floor in its vicinity.

Since the microphones were still in good order, means were sought of making a noise in the water which might serve to return an echo from the bottom, the time-interval to be measured by a stop-watch. There were on board over 1,000 shotgun shells supplied by the Smithsonian Institution for use in securing specimens of land birds from isolated islands. Could not some method be devised for firing these shells under water? The matter was put up to the chief engineer to make a shotgun out of a 20-foot length of brass pipe. Within a short time the pipe was fitted with a shell-holder at one end just long enough to cover the shell, and a firing pin was constructed to be operated by hand at the other end. The operator on the main deck, starboard side, opposite the microphones, leaning over the rail holding the long pipe with the shotgun shell in its holder, about two feet under water would release, when the observer at the microphone blew a whistle, the firing pin exploding the shell. Very often the second echo could be heard and recorded. This method was found by comparison with seven depths determined with unprotected thermometers calibrated for pressure to give depths about 200 meters too shallow. On occasions the agreement was remarkable. With this device soundings were obtained twice or more daily during the remainder of the passage to Callao from November 15 to January 14. When sounding in 300 meters near the coast, seven echoes were heard, and the interval between the shot and the fifth echo was measured.

The vessel passed close to the south side of the various islands in the Galapagos Group but did not stop because of the delay in leaving the Gulf of Panama. In order to make up for some of this delay the loop to Easter Island was shortened by about ten days, with no appreciable loss in the scientific data secured since it was possible to follow previous tracks on the revised loop.

The good weather experienced afforded a splendid opportunity to observe the flights of pilot-balloons almost every day, using the new theodolite supplied at Balboa by the United States Navy. Occasionally the balloon could be followed for over one hour before it disappeared, the average time being about 20 to 30 minutes. With winds of force 5 (Beaufort scale), the balloon would disappear in 13 minutes. Thus excellent determinations of the wind-velocities and directions from sea-level up to a height of from two to six miles were obtained.

The magnetic and electric program was carried out regularly, the good weather and moderate sea giving excellent results. The securing of bottom-samples was made a regular part of the ocean-station program. Twenty-three samples were secured between Balboa and Callao, being chiefly red clay, blue mud, globigerina and radiolarian ooze.

Easter Island was reached December 6 and six days were spent at anchor in the open roadstead of Cook Bay. On 3 days atmospheric-electric observations were secured on shore, simultaneous with observations on board, and for 13 hours continuous observations were made of the magnetic elements at shore-station.

All work had been completed December 12 and the equipment was all on board when the manila anchor-cable parted and the heavy starboard anchor was lost. The rope had worn through on the hard coral sandy bottom, the

wind being fairly strong all the time. This happened fortunately when all were on board and in daylight. The lighter port anchor was put out but it dragged, and it was decided to sail rather than risk the vessel in such close proximity to the rocks without sufficient anchors. Word was accordingly sent ashore for the supply of fresh meat and vegetables to be prepared and sent out to the vessel; in the meantime the ship stood out to sea and back again under easy sail and engine-power. By 3 p.m. all arrangements had been completed and sail was set for Callao.

Manager Edmonds of the ranch at Easter Island was expecting the yearly visit of the company's supply-steamer any day and had assembled the live cattle and sheep which he was to ship to Chile. A radio message from the ship to Washington asking that the company's headquarters at Valparaiso be cabled as to when the steamer was leaving for Easter Island was undertaken. Owing to adverse radio conditions it had been impossible to get the message through and to receive the wireless reply from Washington before eve of departure and to get Mr. Edmonds the message that the steamer *Antarctico* was to sail from Valparaiso December 20. Idling along on the course for Callao, 1,200 miles east of Easter Island, just after dark January 4, the *Antarctico* stopped just astern. She had left Valparaiso, December 29, and Juan Fernandez (Robinson Crusoe Island), January 1. After ten minutes of conversation and wishing each other good luck the two vessels sailed away on their respective courses.

After leaving Easter Island, the *Carnegie* was driven 300 miles out of her course to the south by continuous head-winds. She reached as far as 40°5 south latitude before being able to head up on her course. The southeast trade-wind region was entered January 5 and steady progress was made until reaching Callao on January 14.

On January 8 the shotgun was out of order for the 8 o'clock morning sounding. At 10^h 30^m repairs had been made and a sounding gave a depth of 1,445 meters, as against a depth of 4,000 meters the previous evening. At noon the depth was 1,186 meters, so orders were given to heave the vessel to for a wire sounding and bottom-sample. A water-bottle, with protected and unprotected thermometers, was sent down also. The wire angle was 12° which gave a depth of 1,188 meters, and the thermometer gave a depth of 1,168 meters—a close agreement between all three methods. Thus was discovered a new ridge about 10 miles across and 3,000 meters higher than the surrounding ocean-bed. Soundings were made at intervals of two hours during the afternoon. At 15^h, three miles after the vessel had left the position of the ocean-station, the depth was 1,260 meters; at 16^h, 9 miles distant, it was 2,751 meters; at 18^h, 20 miles distant, it was 3,620 meters, and at 20^h, 32 miles distant, it was 4,115 meters. Ten miles was the distance run between the first sounding of 1,445 meters (25° 03'2 south, 82° 20'0 west) and the sounding of 1,260 meters (24° 54'0 south, 82° 13'0 west) before it began to deepen. This ridge, named "Merriam Ridge" in honor of the President of the Carnegie Institution of Washington, Dr. John C. Merriam, is probably an extension to the northwestward of the peaks terminating in the islands of San Felix and San Ambrosio, 140 miles to the southeast. Time and the limitations of maneuvering a sailing vessel did not permit more exploration in this region.

The last five days of the passage were featured by unusually cloudy weather, so that the program of declination-observations twice daily was not possible. The temperature of the surface water dropped from 21°5 C to 19° C when the vessel was 75 miles southwest of Callao, and remained at 19° C until her arrival, this sudden drop indicating that the cold Hum-

boldt or Peruvian Current which flows northward as far as Ecuador had been entered.

The vessel's position was determined by star-sights early in the morning of January 14, by snap shots on Rigel and Arcturus, seen for brief moments through rapidly moving clouds. Course was then set for the north end of San Lorenzo Island off Callao, and for over 50 miles this course was not changed, approaching to within one mile of the desired point at two o'clock in the afternoon.

During the cruise from Balboa to Callao the following observations were made: 96 declinations, 34 inclinations, 34 horizontal intensities, and 36 ocean- and tow-net stations, 144 sonic depths, 7 atmospheric-electric runs, 36 pilot-balloon flights, 15 series of evaporation-measurements, 48 days of complete potential-gradient records or traces, 54 biological collections, 23 bottom-samples, and the regular continuous records of thermographs and barographs. Observing conditions were excellent during the entire time with the exception of only one or two days.

The stay in Callao was marked by considerable activity in securing new supplies and equipment, in repairs to sheathing and to oscillator, and in making contact with the work of the Department's observatory at Huancayo and in visits and consultations with Observer-in-Charge Ledig and his staff. A new magnetic station was established at the Las Palmas Air-Field, and deflector No. 5 was again standardized. Intercomparisons were made also with the instruments at the Huancayo Magnetic Observatory, and five members of the expedition visited and inspected the Observatory.

The vessel sailed from Callao Bay under her own power at 15^h 20^m, February 5, using the engine until the next morning on account of calm. Here the regular observational program began with an ocean-station and continued without interruption except for a stop of one day at Amanu Island until Papeete was reached on March 13. Excellent weather was the rule with no storms and good breezes. The engine was not required except when the trade-wind was interrupted among the Tuamotu Islands.

The magnetic work was carried out as usual by Torreson, Soule, Scott, Paul, Jones and Ault. Experiments to determine horizontal intensity with marine earth-inductor were continued by Soule and Torreson. Different coils were used and some encouragement was given for ultimate success by the improved agreement of results with those of deflector No. 5. The usual atmospheric-electric program was carried out by Parkinson, assisted on diurnal-variation days by Torreson. Twenty-three complete potential-gradient electrograms were obtained, and three and one-half diurnal runs were made. Considerable time was spent by Parkinson in attempts to operate the radioactive-content collector and some progress was made.

The oceanographic work was entirely successful as carried out by Ault, Soule, Seiwel and Paul, and the deck- and engine-room force under Erickson and Leyer. One of the new bottom-samplers made at Callao gave some trouble by failure to close; the difficulty was overcome by Leyer. The lead weight was countersunk to allow it to fit down over the clamping spring, thus bringing the center of gravity of the falling snapper nearer to the jaws to insure that they strike the bottom in an upright position. Only once did we fail to secure a sample when attempted. The samples themselves have shown considerable variation, the colors ranging from white to grey, light brown, blue-green, coffee-colored, chocolate, and black mud, sand, ooze and lava. One of the new Sigsbee reversing frames was modified to hold two of the Richter and Wiese thermometers and was sent down on the drift-wire 20 meters above the snapper at each ocean-station after

February 27. Thus the bottom temperature and the depth were secured. Experiment showed that it requires 25 meters of vertical haul to reverse the thermometers. Only on rare occasions does a deep-sea reversing thermometer fail to function. Two or three of the unprotected ones required replacement. The water-bottles all reversed and locked properly except on one occasion, when five of the shallow series were reversed too soon for some unknown reason.

During some of the ocean-stations when the vessel was rolling and pitching more than usual, the silk tow-nets were torn by the quick jerking of the ship's motion. Use was then made of the airplane rubber rope, the inboard end of the tow-line being secured to a 20-foot length of rubber rope to ease the strain on the tow-line when the vessel surges. The rubber rope would increase its length to 28 feet at times. The nets have not torn since the adoption of this device, but the seas have been much smoother.

The balloon-work by Torreson, Scott and Ault has been unusually successful due to clear skies and moderately smooth motion. Some thought has been given to possible improvements to increase the efficiency of the theodolite when it is to be used in stormy latitudes. The use of the sextant for measuring altitudes increases the time of following the balloon considerably, especially on rough days. It permits the observer at the theodolite to keep one hand on the counter-weight below to assist in keeping the instrument level, while the other hand operates the horizontal circle screw. If the balloon is lost to the theodolite, the sextant gives its altitude and the approximate bearing of the balloon can be set off on the theodolite by the direction of the sextant pointing.

In view of the length of time required to hold up a sextant and the weight of the new Plath balloon drum-sextant, it became necessary to devise some method for supporting the instrument. One of the deck-chairs was provided with arms and two upright pieces supporting an overhead bar. A fine steel-wire spring was suspended from this bar, and the sextant is now used hanging from this spring. The entire weight is supported at the height of the observer's eye and the freedom of motion is in no wise restricted. The chair can be moved to the most advantageous position on deck for observing the balloon; the ease of operation involves no strain on the observer's arms.

Soon after leaving the Peruvian coast the trade-wind was more southerly than expected, so that it was not possible to follow exactly the route as planned. Later the portion of the 1916 track from 112° west to 17° south was followed exactly. Here it was decided to head west through the Tuamotu Islands direct for Tahiti instead of continuing south around this group. This would increase the value of the oceanographic section, almost due west from the coast of Peru to Tahiti, give additional data as to depths in the Tuamotu group, and avoid near approach to the Rapa Island portion of the present cruise to be made in 1931. Tatakoto Island was sighted early March 7, and on March 8 the vessel was hove to off Amanu Island while the scientific staff made a visit ashore. About 270 people live on Amanu, chiefly engaged in gathering copra. They appear healthy, happy and prosperous, and of a very high class of South Sea Islander. There are no white people on the island.

The oscillator gave excellent service after the repairs at Callao, and a valuable series of soundings was taken by Soule, Jones and Paul. The depth-finder was moved February 8 from the radio-room to the control-room to decrease the crowded condition of the radio-room and to provide for an enlarged program of depth-finding without disturbing the radio oper-

ator at all times of day and night. The depth-finder was completely overhauled February 19 and spare parts substituted for worn ones by Soule, assisted by Leyer. At his request, Paul was instructed in the use of the depth-finder in order to secure a sounding in the early morning in connection with his Greenwich mean noon observations.

On February 16 at 17^h 19^m ship's time, latitude 15°1 south and longitude 98° 20' west, the depth shoaled rapidly from 5,380 meters to 3,403 meters, after which it again deepened to 4,530 at 17^h 29^m, when again there was a gradual decrease to 4,080 meters. Throughout the cruise from Callao to Papeete the bottom has been very irregular, as evidenced also by the many echoes, as many as six surfaces being indicated. While passing through the Tuamotu Group, many soundings were taken in order to develop the bottom-contour in this region. Thirteen soundings were taken March 7, eleven March 8, and nine March 9, giving a valuable contribution to knowledge of the formation in the vicinity of both Tatakoto and Amanu islands. A new ridge 2,000 meters above the general contour was discovered at 17° 40' south and 141° 37' west between Amanu and Hikueru islands. A few miles later at the ocean-station, hard bottom with a few fragments of black lava and no trace of ooze, showing possibility of fairly recent volcanic origin, was found.

During the cruise from Callao to Papeete, the following observational program was carried out: 63 declination-stations, 17 inclination- and horizontal-intensity stations, 3½ atmospheric-electric runs, 23 potential-gradient traces, 17 ocean-stations (including tow-nets and plankton-pump), 210 sonic depths, 35 balloon-flights, and 9 evaporation-series.

Sailing from Papeete on March 20, the easterly trade-wind was picked up March 24, and this breeze continued until March 28. The usual program of work was carried out daily. Pago Pago was reached April 1.

Considerable time was spent in trying to operate the new Coast and Geodetic Survey type sounding-machine, which had been installed on the port side of the quarter-deck, aft near the meteorological shelter-house, during our stay in Papeete. The machine is built so that the drum is floating and must be moved along its axis to engage either the brake or the clutch. When the vessel rolls, the tension on the brake is changed by the movement of the drum so that the speed of paying out can not be kept under control. When paying out on the clutch, letting the weight of the snapper unreel the drum against the motor, the momentum of the drum becomes too great for the speed at which the snapper is going down and the wire slackens and kinks. To stop it, the drum must be moved away from the clutch, through neutral or no control, across to engage the brake, and hence is stopped with a jerk which parts the wire. The drum did not hold more than 4,700 meters of wire, so in Apia it was machined out to hold 7,000 meters. This experimental work was very expensive of bottom-samplers and wire, so that no bottom-samples were obtained during this part of the trip.

On the passage from Tahiti to Samoa, the following observations were made: 20 declinations, 6 inclinations and horizontal intensities, 6 ocean-stations, 70 sonic-depths, 10 pilot-balloons, daily atmospheric-electric observations and one diurnal variation, and 2 evaporation-series. After taking on gasoline, oil, and kerosene at Pago Pago, the vessel left for Apia on April 5, arriving the next morning, going the entire distance under engine-power.

After completing the work of intercomparing magnetic instruments with those of the Apia Observatory, standardizing deflector No. 5, and carry-

ing out simultaneous ship and shore potential-gradient observations, the *Carnegie* sailed from Apia April 20 en route for Guam. By eight o'clock the next morning when the vessel was about 65 miles from Apia, two stowaways were found on board. As there was no place for them on board the vessel, it was decided to return with them to Apia, in order to avoid future trouble and expense, thus losing one day and a half.

Soon after leaving Apia the second time the wind became favorable and the engine was stopped. During the following week the winds were variable and calms were frequent, until April 28 when the northeast trade-wind began. This breeze continued without interruption until arrival at Guam May 20. The regular daily program was carried out in spite of frequent rain-squalls, which, however, were usually of short duration. May 6 was skipped due to crossing the 180th meridian of longitude.

Wake Island was sighted early on May 11, and the vessel passed within one-quarter mile of Peacock Point, the southeast point of the island. Observations taken checked the position given for the island by the U. S. S. *Tananger* Expedition of 1923. The highest point is only 21 feet above sea-level; there are no cocoanut trees, only low-spreading umbrella trees and shrubs. Numerous birds were flying about. No signs of life or of buildings were seen. Glimpses of the beautiful green-blue lagoon seen through the break in the south side showed a considerable area free from obstructions, which might make a suitable harbor and landing for seaplanes. Rota and Guam islands were sighted May 19, and early May 20 the vessel was safely moored in Port Apra, Guam.

Between Apia and Guam the following observations were made: 49 declinations, 13 inclinations, 13 horizontal intensities, 14 ocean-stations, 20 pilot-balloon flights, 3 atmospheric-electric runs, 15 complete and 13 incomplete potential-gradient traces, 159 sonic depths, and 3 bottom-samples.

After several further attempts to use the new Coast and Geodetic Survey sounding-machine, we decided to resume use of the winch as before. On April 24 the 4-mm. aluminum-bronze bottle-wire failed in seven or eight places, the heart-strands breaking near the points where water-bottles were usually clamped. This wire had been in use since Balboa, October 1928. It was necessary to discard about 2,700 meters. With over 4,000 meters of wire out, 120-pound lead weight on the end, and seven or eight bottles in series, the strain on the wire is very great, especially with any current. On the same day, difficulty in controlling new sounding-machine caused break in piano wire and loss of snapper No. 7. The piano wire was shifted to the winch on April 25, but owing to shortage of snappers no bottom-samples were secured after April 28 until en route from Guam to Japan.

The sonic depth-finder results were of unusual interest in that many shoals and deeps were crossed, showing a generally mountainous region on the ocean-floor. One region varied in depth from 6,500 meters to 4,000 meters and back to 5,700 meters. Another varied from 5,600 meters to the scientific staff 3,800 meters, to 1,900 meters and back to 5,800 meters. chiefly engaged in gathering Guam at 14° 32' north and 147° 28' east, the perous, and of a very high the previous depth 20 miles northeast being 2,892 people on the island. east end of Nero deep.

The oscillator gave excessive. Sumay was reoccupied. The stay was all too valuable series of sounding the generous hospitality which was extended depth-finder was moved Febley and the Navy and Marine personnel, as room to decrease the crowdechey of the Cable Station, who placed his home for an enlarged program of depauffeur, at our disposal.

After taking on fresh water and gasoline, the vessel sailed for Yokohama on May 25. The easterly trade-wind holding for four days, good daily runs were made. The wind then shifted to the south and varied between south-east and southwest until June 2. On the night of June 1 there were received by radio from the Manila Observatory through amateur station K1AF the positions of a typhoon for the two preceding days. The wind had been increasing in force all afternoon and the sea was becoming heavier. These positions were at once plotted on the chart and the path predicted which the storm-center would follow. By rough estimation of its rate of travel, it seemed about to intercept the track within a few hours. The barometer had dropped 4 mm. during the preceding 8 hours and it seemed wise to head east by south and place the vessel in a safer position to avoid the path of the storm. After running eastward for 2 hours, the barometer began to rise and the wind moderated, so the vessel was hove to waiting for wind and sea to moderate further. After 2 hours, sail was set and the vessel proceeded again on her course toward the northwest, riding on the tail of the typhoon. The wind continued to shift to the right, showing that the storm had passed on to the eastward. There followed 4 days of rough sea, contrary winds, and engine-running. When within 15 miles of the entrance to Tokio Bay, June 5, a rapidly falling barometer and rainy threatening weather made it advisable to heave the vessel to in order to judge the nature of the storm and to see the headland. After waiting 2 hours, conditions became worse and it was decided to get off shore to increase the margin of safety. After running the engine 5 hours, the wind and sea had risen to such an extent that it was necessary to heave the vessel to and ride out the typhoon about 20 miles off shore and apparently near the center of the oncoming typhoon. About noon the barometer appeared to reach its lowest point and became steady. The wind began to moderate and back from south toward west. The storm center apparently had passed to the west and north. Two sails were lost and several minor accidents happened on deck, but the vessel rode through the heavy seas in good order. By early morning June 7 the sea had moderated and the wind had shifted to north-east. Sail was set and by 11 a.m. Tokio Bay was entered and Yokohama was reached under engine-power about 8 o'clock in the evening.

The following observations were made while en route from Guam to Yokohama: 20 declinations, 6 inclinations, 6 horizontal intensities, 5 ocean-stations, 9 pilot-balloon flights, 5 bottom-samples, 50 sonic depths, one atmospheric-electric run, 5 complete and 8 incomplete potential-gradient electrograms, and 4 bottom-temperatures.

With the sonic depth-finder a new deep was discovered May 29 at 23°8 north and 144°1 east and was named "Fleming Deep" in honor of the Assistant Director of the Department. The greatest depth observed was 8,650 meters. The deep was traversed in a south to north true direction and was 9 miles wide at 8,600 meters, 20 miles at 8,000 meters, 34 at 7,000 meters, 47 at 6,000 meters, 74 at 5,000 meters, 106 at 4,000 meters, and 162 miles wide at 3,000 meters depth.

During the stay in Japan, intercomparison observations were made at the Kakioka Magnetic Observatory. The expedition and members of the staff were shown every courtesy and attention by the scientists of Japan as well as by members of the foreign colony. Some bottom-snappers were made, together with lead weights, and an experimental azimuth-chair for use with balloon-sextant was constructed. The *Carnegie* sailed for San Francisco on June 24, and at the close of the report-year was en route from

Yokohama for San Francisco, being then in latitude 38° north and longitude 147° east.

A summary of the work done on the cruise as far as Yokohama shows about 33,000 nautical miles covered in 274 days at sea, 381 declinations, 125 inclinations, 126 horizontal intensities, 112 ocean-stations (for temperature, salinity, hydrogen-ions, phosphate, and plankton), 116 complete and 67 incomplete days of potential-gradient records, 56 complete diurnal-variation eye-reading runs (16 ionic content and 20 each conductivity and penetrating radiation) and 18 incomplete runs of other atmospheric-electric elements (7 ionic content, 5 conductivity, and 6 penetrating radiation), as well as numerous daily determinations (55 potential gradient, 151 ionic content, 184 conductivity, 174 penetrating radiation), 965 sonic depth-determinations, 110 balloon-flights, 37 evaporation-series, besides continuous records of barograph, sea-surface thermograph, wet- and dry-bulb aspirating thermograph, three wet- and dry-bulb electric resistance-thermographs, daily meteorological and Greenwich mean noon observations.

Preliminary communications on the results obtained have been prepared on board as shown by the brief abstracts on pages 248 and 250. In addition, reports upon the various classes of work have been regularly submitted by the responsible observer together with suggestions for improvement. The valuable store of geophysical data and specimens obtained thus far speak well for the fine spirit of cooperation and industry on the part of each member of the scientific staff as well as of the officers and men on the sailing staff.

The scientific staff remains as in the last report except that Seiwel, biologist and chemist, was relieved at Apia to take a curatorship with the Buffalo Museum of Science. H. W. Graham of the Carnegie Museum of Pittsburgh was appointed to fill this vacancy to join the party at San Francisco in August 1929, after a month spent at the Scripps Institution of Oceanography at La Jolla, California.

LAND MAGNETIC SURVEY¹

COOPERATIVE WORK

Because of the concentrated effort placed upon the work of the *Carnegie* during Cruise VII now in progress, land magnetic survey-work has been limited to certain cooperative projects carried on with other persons or organizations as follows: (a) With the Department of Physics of the University of Cape Town; (b) with O. Dahl, on furlough from the Department; (c) with the Byrd Antarctic Expedition.

During the year two expeditions were conducted with the cooperation of the University of Cape Town. The first was a short expedition to the east coast of Natal and the second, during the longer vacation at the University, to Southwest Africa, where stations of Morrison in 1909 and of Sawyer in 1916 were reoccupied. The cooperation with O. Dahl during his expedition of travel and exploration under other auspices gave valuable secular-variation and distribution data at stations in Syria, Iraq, Persia, Baluchistan and India. The cooperation with the Byrd Antarctic Expedition included training of observer in the use of magnetic and atmospheric-electric instruments and in observatory routine, and extensive instrumental equipment was furnished: Radio advices received from time to time indicate that

¹ From the report of the chief of section, H. W. Fisk.

valuable results are being obtained by the observers with this equipment at their base-station at Little America on the Bay of Whales.

Preliminary arrangements have been made for the loan of equipment to Director A. Walter of the Meteorological Service of British East Africa, with which he proposes to reoccupy magnetic stations in Uganda, Kenya Colony, Tanganyika Territory, Northern Rhodesia, and possibly southern Sudan, in connection with an expedition throughout this territory for the purpose of inaugurating a comprehensive meteorological service in the interest of aeronautical developments. It is expected that this work will begin toward the end of the present calendar year.

REDUCTION OF LAND OBSERVATIONS

Revisions of the field-observations have been kept current in the office. Manuscript for all the observations made during the years 1927 and 1928, including the descriptions of stations, observers' reports, and related matter as for previous volumes of our *Researches*, have been revised and tabulated for publication by Duvall.

FIELD-OPERATIONS

The following summaries from field-reports indicate the scope of land work executed during the year:

Africa—Continuing the resurvey of South Africa begun in December 1927, with cooperation from this Department through financial assistance and the loan of instrumental equipment, E. N. Grindley of the Department of Physics, University of Cape Town, sailed June 26, 1928, for Durban, Natal, where he arrived on July 1. This station was especially well selected for secular variation, as systematic declination-observations had been made at the observatory located there from 1894 to 1904. The station was also occupied by Sawyer of the Department in 1916. These observations indicate that the annual rate of change of declination which had increased from about 5 minutes (decreasing westerly) in 1894 to a maximum of more than 15 minutes some time between 1904 and 1916, is now diminishing, the mean over the 12 years being about 12 minutes. This result is confirmed by observations at Gingindhlovu which was occupied July 13–16, 1928. From these results it may be inferred that the focus of rapid annual change in declination is moving westward, the center having passed these two points. Observations at stations in Orange Free State made earlier in the year showed the rate to be still increasing as the center approached those stations in the westward movement. The annual rate of decrease of horizontal intensity is phenomenally great over the whole of South Africa, the mean rate at Durban and Gingindhlovu being in excess of 100 gammas annually for the years 1916 to 1928. What changes are taking place in the form or position of this unusually active focus, which seems to include most of South Africa, observations so far made do not disclose. On this expedition observations were made also at Bethlehem, Orange Free State, and at Mooi River, Natal, near J. C. Beattie's station of 1903 at Fountain Hall. Unfortunately the observations at the latter place were made during the very unusual magnetic storm of July 8, 1928, and those at the former station were in large measure vitiated by the presence of an artificial disturbance which the limited time available for the expedition did not permit the observer to investigate. Diurnal-variation observations were made of all three elements at Durban and Gingindhlovu.

A second expedition was made during December 1928 to February 1929 to Southwest Africa; stations in ten localities were reoccupied, and diurnal-variation observations were made at four stations, namely, at Windhoek, Kalkfeld, Swakopmund and Mount Brukkaros, the last named being a new station established at the Smithsonian Solar Observatory. Grindley was cordially received by the officials in the office of the Administrator at Windhoek, who took a great interest in his expedition and lent very valuable assistance. The old station at Windhoek was easily identified and reoccupied as closely as altered conditions would permit. A narrow-gage railway extends northeastward about 500 km. and serves the mining district centering about Tsumeb, running heavy ore-trains to which passenger coaches are attached. Desiring to take advantage of the favorable season, Grindley proceeded by this railway directly to Kalkfeld, Otavi and Tsumeb, stopping on the return at Kalkfeld to complete the program of diurnal-variation observations, that place being more suitable than either Otavi or Tsumeb. Otavifontein was noted as of unusual interest in possessing a stream of water which flows throughout the entire year, a rare phenomenon in this arid region. The seaport at the terminus of the railway is Swakopmund, where the climate contrasts strongly with that in the interior, the mornings and evenings being damp and chilly with a sea-fog until near midday, when the conditions change to hot and sultry. After a full "class I" program, that is, including observations for diurnal variation in all elements, and after making a visit to Walvis Bay which was found to be quite unsuitable for a secular-variation station, Grindley went by rail to Karibib which is at the junction of the ore-road from Tsumeb to Swakopmund and the road which traverses the Colony from south to north and connects with the road to Cape Colony. A close reoccupation of the C. I. W. station of 1909 was made on January 24-25, after which he continued southward by rail to Gibeon, where the repeat-station of 1909 and 1916 was closely reoccupied. From here arrangements were made by telephone for transportation to the Smithsonian Observatory at Mount Brukkaros, where Grindley was the guest of the observatory staff. As transportation by motor was possible but halfway up the side of the mountain, the remainder of the journey was made on foot with the heavier luggage carried by donkeys. A "class I" station was established with an auxiliary station January 31-February 4. Through the courtesy of Director Hoover, arrangements were made for transportation back to the railway at Keetmanshoop, where the repeat-station of 1909 and 1916 was reoccupied, though incompletely owing to cloudy weather. The railway which parallels the coast about 200 miles inland makes a junction at Seheim with a branch running to the seaport at Luderitzbucht. In 1909 Beattie did not establish a station at the port, but some 10 miles inland at Rotkuppe. The latter was found to be now quite unsuitable, as it is uninhabited, a mere halt in the desert where food and water were unobtainable. Furthermore, as it is in the diamond fields, official permission and the presence of an officer would be required to prevent illicit diamond-hunting. The station was established at Luderitz instead. Reoccupation of Aus and Seeheim which had been occupied in 1909 and 1916 completed the expedition on February 19, 1928. Thirteen localities had been occupied, at five of which auxiliary stations had been established. With the exception of Mount Brukkaros and Luderitz, all the localities had been previously occupied by C. I. W. observers, six of them in both 1909 and 1916. "Class I" observations were carried through at three of the stations. The average field-expense was a little less than \$27 per locality.

Asia—During a furlough to be devoted to travel and exploration, Odd Dahl of the Department's staff traveled from the Mediterranean coast, through Syria, down the Euphrates to Baghdad, overland to Teheran by motor-car, thence using the same car to the eastern borders of Persia. A special arrangement was required to secure permission to cross Baluchistan with the car, but the passage was allowed so that the entire journey across India to Calcutta was successfully completed. The first magnetic station was attempted at Aleppo, but was left incomplete on account of a violent sand-storm. On July 26, 1928, Dahl left Aleppo for Djerablous, Syria, a small village on the Euphrates near the Turkish border, at which a station was established. From here he planned to go by a small boat to Baghdad, depending mainly on the current to carry him along. Stations en route were established at Meskenah, Rakka and Abu Kemal. Progress by this method of travel became progressively slower as the river widened in the plain country, so that it was decided to try to find other means of travel. At Ed-Deir through the cooperation of the officers of the French garrison it was possible to purchase a nearly new automobile by means of which the party arrived at Baghdad on September 2. Observations were made at Baghdad and at Babylon, and the journey continued over a fair road to Teheran, at each of which places there were previous C. I. W. stations though these could not be closely reoccupied. Continuing the journey by a route which carried him well to the north, no practicable route being available for automobiles farther south, Dahl established six stations in Persia and two in Baluchistan before arriving at the Indian border. In crossing India, stations were occupied at Channu, Lahore, Delhi and Benares. Dahl completed his special mission and sailed for Antwerp from Calcutta on December 22 and returned to Washington in May, having visited Norway and made observations at Oslo en route.

Australia—No field-expeditions were undertaken; observational work was limited to that required in the operation of the Observatory at Watheroo.

Europe—Dahl made observations at Oslo, Norway, in April while en route from India to Washington. The magnetic observers on the *Carnegie* made a comparison of their magnetic instruments with the standards at Seddin, Germany, June 27–30, 1928, during the stay of the vessel at Hamburg. A station for standardizing the ship-instruments was also occupied at Finkenwärder in the Elbe River near Hamburg, July 2–4.

North America—No field-expeditions were undertaken, and only the necessary standardizing observations were made at Washington in connection with instruments returning from or going out to stations abroad.

South America—The *Carnegie* party made observations on the Las Palmas aviation-field near Lima, January 23 to February 2, 1929, and comparisons at the Huancayo Magnetic Observatory on January 24. In addition, the regular routine observations have been carried on at the Observatory throughout the year.

Islands Atlantic Ocean—After leaving Hamburg, Germany, the *Carnegie* put in at Reykjavik, Iceland, and reoccupied the station established on Cruise III on Engey's Island, September 24, 1928. The next port was Bridgetown, Barbados, British West Indies, and here the repeat-station of 1905, 1908, 1919 and 1923 was exactly reoccupied.

Islands Pacific Ocean—Leaving Panama en route to Callao, Peru, the *Carnegie* cruised southwestward to Easter Island, which had been previously visited in 1916 on Cruise IV; the magnetic station was occupied on December 8–11, 1928. The vessel called at Apia, Samoa, and compared instruments with those of the magnetic observatory there April 10–18, 1929,

and also reoccupied the station at Sumay, Guam, May 22, on the way to Yokohama. Another comparison of standards was effected June 13-15, 1929, when the ship's standard instruments were taken to Kakioka and a comparison made with those of the Japanese Observatory at that place.

Antarctic Regions—A temporary magnetic and electric observatory was installed on the ice at the base-station of the Byrd Antarctic Expedition and was put into operation with equipment provided by the Department. F. T. Davies is in charge of the magnetic work at the station, having received the necessary training at the Department.

OBSERVATORY-WORK¹

The successful operation of the Department's magnetic and electric observatories and of its cooperative observatory-work is shown by the following brief summaries:

Watheroo Magnetic Observatory, Western Australia—The Watheroo Magnetic Observatory is situated in latitude $30^{\circ} 19' 1''$ south and longitude $115^{\circ} 12' 6''$ east of Greenwich, 800 feet above sea-level. The magnetograph, earth-current recorder, potential-gradient apparatus, and the positive and negative conductivity-apparatus were continuously operated. Complete hourly tabulations of their records were scaled and checked and forwarded to Washington for final reduction.

The necessary work of a magnetic observatory was performed. The preliminary mean annual values of the magnetic elements as deduced from the magnetograms for all the days of the year 1928 are: Declination, $4^{\circ} 15' 0''$ west; horizontal intensity, 0.24656 C. G. S. unit; vertical intensity, -0.51070 C. G. S. unit; and inclination, $64^{\circ} 13' 8''$ south. The preliminary values of the annual changes in the magnetic elements for the period 1927.5 to 1928.5 are $1' 3''$ east in declination, 15 gammas decreasing in horizontal intensity, 41 gammas decreasing numerically in vertical intensity, and $1' 9''$ south in inclination.

During the report year the difference in potentials between the sub- x electrodes of the earth-current system was recorded. The variations in the diurnal values show general agreement with previous years. A new electrode was placed at the position R . It was buried two feet deeper than the other sub- x electrodes in the hope that thereby its difference of potential from the electrode at O_s would be within the limit of the recorder on the sensitivity now in use during even a very dry season. Provision was made for a chronographic trace on both sides of the earth-current record. The design of the electro-magnetic recording attachment on the left-hand side of the recorder was modified to suit the right-hand side and an attachment manufactured in accordance with this design. The recording pens are readily adjustable so that exact simultaneity may be obtained between the two pens and the print-wheel. Ready means were also provided for manual deflection of the chronograph-pens so that their adjustment may be tested daily.

Atmospheric potential-gradient observations were maintained. Stricter attention was paid to elimination of leak, and more adequate leak-tests devised. Leak-tests of all the insulators in the inner conducting system of the potential-gradient apparatus are automatically performed seven times daily by the use of the program-machine. In order that these tests may be completely valid, the insulation-resistance of the sulphur insulator in the collector-rod, which is part of the inner system, is measured at the necessary intervals and its insulation-resistance is always maintained so that the leak across the sulphur insulator is never greater than 0.3 per cent per minute.

¹ From the reports of the observers-in-charge.

Adequate standardization-observations were taken for the control of the reduction-factor. The mean of the six series taken during the year is 1.12 which agrees almost exactly with the average of 1,150 hours from the 1,800-hour series taken last year in order to evaluate the factor. Investigations of the suitability of various types of collectors were continued and six experimental rod-collectors, in which ionium is used for the ionizing agent, have been made. Approximate absolute values of the conductivity of these collectors were obtained by suspending them in an artificial field. Their effective conductance was determined from readings of the increase in potential of the collector-system with time after earthing, having due regard to the measured capacity of the collector-system and the insulation-resistance of the insulators for the collector-system. During the observations the significant condition was developed that consistent results were obtained only when artificial ventilation of a definite minimum value was provided for the collector-system.

Experiments were made using a water-dropper for a collector in the Simpson method of making potential-gradient standardization-observations. It was found possible to manufacture water-dropper collectors of high activity. With a field set-up of 300 cm. capacity, half-value potential was reached in 14 seconds using a water-dropper (our standard collectors reach half-value in 30 seconds). Standardization-observations were made using this very active collector. The insulation of the field collector-system was maintained at approximately 0.3 per cent per minute; therefore, in the light of our present knowledge, the potentials recorded were within a small portion of 1 per cent of the true atmospheric potential. These observations indicated that the reduction-factor is 1.13 or 1.14.

The resistances across the circuit supplying the quadrant-potentials of the electrometer were increased to 1.9 megohms by the use of two paired metallic resistances. The proper insulation-precautions made necessary by the enormous resistance of the circuit were obtained by mounting the cells supplying the quadrant-potentials in sulphur and making all other insulators in the circuit of amber. The calibration-switchboard for the potential-gradient apparatus and conductivity-apparatus was rebuilt, using sulphur and amber insulations instead of ebonite. Advantage was taken of the opportunity to rearrange the wiring so that a bifilar electrometer might be used for measuring the various calibrating and operating potentials.

Observations were continued with the apparatus for recording the positive and the negative conductivities of the atmosphere. The preliminary mean value of the positive conductivity for the year 1928 is 1.80×10^{-4} E.S.U., and of the negative conductivity 1.53×10^{-4} E.S.U. These are practically the same as the values for 1927. The average value of the potential gradient for 1928 was 82 volts per meter. This is an increase of 3 per cent over the year 1927, which in turn was 3 per cent greater than the year 1926.

A duplicate device for applying the hourly scavenging high potential to the conductivity-apparatus was designed and manufactured. Prior to having these devices, the scavenging potential for obtaining the hourly zero was applied simultaneously to both the positive and the negative apparatus. The result was that for 7 minutes in each hour no record was obtained of either the positive or the negative conductivity. Interpolation over this period was uncertain, more especially on disturbed days. Now that the duplicate device is available, the operating routine has been arranged so that the positive zero is obtained at the half-hour while the negative zero is obtained at the hour. Thus there is now a complete record of the atmos-

pheric conductivity and it is possible accurately to interpolate over the hourly zero-periods.

During the year, weekly determinations have been made of electrometer-sensitivity. In order to increase the accuracy and rapidity of the measurement, two single-pole, double-throw sulphur switches numbered 7 and 8 have been added to the apparatus. The following operations are now necessary for a determination of the electrometer-sensitivity: Manual contactor down, switch number 2 open, and switch number 7 down. The terminals of the potentiometer which supply the calibrating potentials are attached to the binding posts marked + and -. With that arrangement, when switch number 8 is thrown upwards, the zero-position of the needle is obtained, and when it is thrown downwards the positions of the needle corresponding to the calibrating potentials are found.

A new friction-pin for the recording drum was designed. It was made up in Washington and has proved successful in use. The calibrating drum was rewound and the number of effective turns is now 77. An investigation was made to ascertain the reason for the shift in the zero-position of the negative conductivity-spot and some of the causes removed. Builder completed a paper entitled "The effect of condensation nuclei and water vapor on the atmospheric-electric elements."

The Council for Scientific and Industrial Research of the Australian Government lent an atmospheric recorder to the Observatory. The recorder, which R. A. Watson-Watt had used at Slough, England, was purchased from the Radio Research Board of England. The Council bore the cost of erecting a building to house it. Wood has been responsible for assembling and running the recorder, which has been in continuous operation since November 1, 1928. The recorder consists of a large frame aerial which rotates around a vertical axis once every 15 minutes. The incoming atmospheric are passed through a five-stage amplifier. The output from the last stage is recorded on a drum by means of a syphon-oscillograph of the Abraham-Bloch type. Wood is making a study of the records. An examination of the synoptic meteorological data as published by the Australian Government reveals that the centers responsible for the main streams of atmospheric are more distant than the deduced locations of areas of low pressure and thunderstorm-centers.

Next year it is hoped to make some wireless research experiments in reception and transmission. As this entailed erecting receiving and transmitting aerials which would have changed the potential-gradient reduction-factor, were the wireless cabin to remain in its original position, the cabin was moved 250 feet in a southeast direction where the necessary masts were erected. The Australian Government has given us the station No. VK6MO. Builder has been responsible for the successful establishment of the station both for transmission and reception. The Eastern Australian states have been consistently worked, using 200 volts from small storage-batteries, nominal 2 ampere-hour size, with 2 to 3 watts output. Lately, with increased power using 300 volts, schedules are being maintained with New Zealand and the Philippines.

Under the heading of miscellaneous scientific activities may be mentioned the following: Preparation of wiring diagrams to show the alteration in the conductivity-apparatus wiring, the potential-gradient-apparatus calibrating wiring, and in the switchboard for calibration-control of these apparatuses. A separate clock-line from the Delco room to the atmospheric-electric building was strung as it was found that there were induction-effects during conductivity-calibrations more especially at the hour and half-hour. The

time-control circuits from the program-machine were rearranged so that the instruments were as far as possible on separate lines. It is now possible to employ the time-control most suitable to the particular apparatus. A second zero-stud was placed in each of the boxes containing silver-chloride batteries. When the wander-plug is placed on the second stud, that particular box of batteries is eliminated from the circuit. Since time could not be spared for a member of the staff to attend the Conference of Physicists, Mathematicians, and Astronomers in Canberra held in August 1928, Professor Ross presented two papers by members of the staff entitled "On the redetermination of the reduction-factor at Watheroo," and "The Watheroo Magnetic Observatory potential-gradient collector." As in former years, meteorological observations were made and tabulated. The earth-current aerial lines were reconditioned following a bush-fire that severely damaged two miles of line.

Dr. A. D. Ross, Professor of Physics at the University of Western Australia, continued to assist the Observatory in every possible way. The Minister of Customs materially assisted the work by passing in duty free many scientific supplies, a well-equipped lathe, and some of the replacements required for the truck.

H. F. Johnston continued in charge and was capably assisted by observers J. E. I. Cairns (till August 9, 1928), F. W. Wood, and G. Builder (after August 11, 1928), and by Mechanic S. W. Caswell. During vacations temporary assistance was supplied by the following students in the Physics Department of the University of Western Australia: G. A. McIntyre, S. E. Coalstad, G. R. W. Meadley and V. R. Brown.

Huancayo Magnetic Observatory, Peru—The Huancayo Observatory is in latitude $12^{\circ} 02'7$ south and longitude $75^{\circ} 20'4$ west of Greenwich at an elevation of 11,000 feet above sea-level. The magnetograph has been operating continuously during the year with a minimum of loss of trace through accidental failure or other difficulties. The usual weekly absolute magnetic observations have been made regularly and monthly scale-value deflections made on or near the fifteenth of each month. The horizontal-intensity variometer and the declination variometer have given no trouble, but the vertical-intensity variometer has shown shifts in the trace far too frequently. This has usually occurred at the time of the temperature-readings or when scale-value deflections were being made, but there have been a number of shifts when the observer has not approached the instrument. Magnetometer-inductor No. 16 was brought from the Department by Rooney on May 24 for field-work in the nearby regions of Peru.

The atmospheric-electric instruments, the conductivity-apparatus, and the potential-gradient recorder have been recording continuously with only the normal loss of trace caused by lights burning out or relays failing to function. On December 17 to 21 the positive conductivity-apparatus was taken down, the electrometer rebalanced to put the spot in a better position on the trace, and a new lens installed to improve the spot. The quadrant-potential batteries for the potential-gradient recorder have given some difficulty and have had to be replaced several times because of the poor condition of the silver-chloride cells, but the instrument has given no other trouble. Monthly potential-gradient reduction-factor determinations have been made when the weather has permitted.

The earth-current recorder has been operating continuously the greater part of the year, though as in previous years the breakage of poles has caused considerable loss of record and extra work for members of the staff.

During the latter part of 1928 all but two of the multiple-wire poles were replaced with concrete poles, and more recently most of system I has been transferred to concrete poles. During the progress of this work there was considerable interruption to the regular recording from all lines, but they are now recording with a minimum of interruption. The recorder was overhauled once during the year, and the slide-wire was replaced by a new one on August 14, 1928, followed by a marked improvement in the accuracy of the recording.

All the meteorological instruments have been operating satisfactorily and with practically no loss of record.

The scaling and tabulation of data from the records of the various instruments has suffered seriously during the year on account of the work on the concrete-pole program. This work was almost ten months in arrears, but concentrated work on the part of the staff has recently cut this down to not more than an average of six months in arrears. Monthly reports on magnetic storms, magnetic daily characters, conductivity scale-value data, and on potential-gradient reduction-factor determinations have been kept up with only occasional delays in forwarding them to the Office.

Good progress has been made during the year in the program of replacing the old eucalyptus earth-current poles with reenforced-concrete poles made at the Observatory, as well as in replacing by reenforced-concrete posts a large number of the wooden fence-posts. The design by Ledig and tests of concrete poles for the earth-current replacements may be of interest as they have been found satisfactory. The poles are in two sizes designed to carry one or two and four to six wires. All are triangular in section with corners bevelled back about an inch at each corner with a half-inch diameter reenforcing rod in each corner. Three-eighth-inch rods were originally used, but vibrations incident to hauling the cured poles to the field were too severe, several being broken in hauling; consequently the heavier rods were used and were found quite satisfactory, no poles being broken despite much larger hauls. (Broken poles of the lighter reinforcement were used at sharp turns of the line as "dead-men.") The larger poles are 20.5 feet long with 10-inch and 8-inch faces at the bottom and top, respectively; the corresponding dimensions for the smaller poles are 18.3 feet, 8.5 inches and 6.5 inches. All poles are made with one of the reenforcing rods projecting about 4 inches at the bottom and 4 inches at the top to give better lightning protection. In planting the poles a few inches of clay soil is first put into the hole to give better ground-contact for this rod. Suitable forms are easily made. The most important feature in making the poles is to allow ample time for thorough curing after casting.

A thorough survey was made along the Chupaca River in preparation for the application for the Observatory's water-supply permit, and application is now being made with the Ministerio de Fomento through an attorney recommended by Ambassador Moore for this concession. All arrangements have been made for the installation of the ram-system of supply and pipe-lines of about three-fourths mile with a lift of about 160 feet to the Observatory site.

The Delco generator-engines have been overhauled and the electric water-pump repaired. A cheaper grade of engine-oil for the Delco engines was tried and found to result in smoother operation, besides doubling the operating time between overhauls. Three sets of storage-battery plates have been replaced during the year, and the electrical system is now in excellent condition. A new truck was received in July 1928 and has given invaluable service, both in trouble-free operation on the usual trips to Huancayo for

supplies and for heavier shipments. In the task of hauling the concrete poles to the field a trailer is used.

The American staff—P. G. Ledig, Observer-in-Charge, and observers S. E. Forbush and V. J. Eaton—has remained practically the same during the year and has done well in keeping the Observatory in the best operating condition. On May 24, W. J. Rooney arrived from the Office on a special assignment of earth-resistivity measurements. On June 8, S. E. Forbush left the Observatory for the United States for assignment to the *Carnegie* on arrival in San Francisco; Robert E. Gebhardt of the Case School of Applied Science will arrive to take his place early in July. Señor Quintana has done good work and has been largely responsible for the original scaling of traces. Feodoro Astete, a graduate of the Instituto Andino of Huancayo, has been doing various routine tasks at the Observatory with complete satisfaction and will be used as circumstances permit in the future. Among the workmen, Pascual Reyes, the electrician, Benjamin Antesano, the carpenter, and the two laborers, Francisco Melgar and Francisco Espejo, deserve especial commendation. Other laborers have been employed as occasion demanded, and a number of good men have been found for later work.

"A gringo visits the Huancayo Magnetic Observatory" for the West Coast Leader, and two articles descriptive of the work of the Carnegie Institution (one on the Department of Terrestrial Magnetism and one on the Observatory) for the *Revista de Marina* were written by Forbush. He also prepared preliminary discussions on the variations of the horizontal-intensity base-line values and scale-values with tabulations and graphs of the declination and vertical-intensity base-lines. The scale-value least-square formulæ for horizontal intensity show excellent control and also that the temperature-compensation for that instrument is quite satisfactory, the temperature-coefficient being less than 2 gammas for a temperature-change of one degree Centigrade.

As in other years, visitors from Huancayo and from other parts of Peru have been frequent and have taken an appreciable amount of the observers' time. A number of the staff of the *Carnegie* visited the Observatory during the vessel's stay in Callao, and in turn Forbush and the Observer-in-Charge visited her during the stay there. E. P. Killip of the Smithsonian Institution and his assistant, A. C. Smith, spent several days at the Observatory during their stay in the Sierra en route to the Amazon valley and made considerable additions to their plant-collections while here.

Ten barrels of cement were contributed to the village of Pincha to help in building a new bridge over the Chupaca River at the point formerly called the Bridge of San Juan and other assistance was given as occasion permitted; good progress was made on this improvement. In appreciation of the assistance given, the Sociedad de Pincha has elected the Observer-in-Charge as Honorary President.

As always, the United States Embassy has been consistently helpful in obtaining free-entry for Observatory supplies. The government officials of Peru have maintained their helpful, interested attitude in the work of the Observatory as heretofore—an attitude evidenced in many ways and having much to do with the successful realization of the scientific program.

Washington, United States—Photographic registrations of air-potential and of negative conductivity were continued throughout the report-year in the Deck-Observatory of the Laboratory at Washington under the attention chiefly of Sherman. The quantity of satisfactory records was 86 per cent for the potential and 71 per cent for the conductivity. During the calendar year 1928, 161 of the potential records were free from negative potential.

The mean potential from these is 143 volts, which gives a gradient of 150 volts per meter on the basis of a reduction-factor of 1.05 as tentatively used in the last two preceding annual reports. In the year 1928 a reduction-factor was determined on six different occasions by Wait and Sherman. The mean from 80 sets of readings is 1.17 as compared with 1.13 of the previous year. The cause of this tendency toward larger reduction-factors in recent years is under investigation. As in past years, this Observatory has also continued to serve as an experimental station for the tests by Gish, Wait and Sherman of newly-designed apparatus and improvements in existing atmospheric-electric equipment for assignment to the Watheroo and Huancayo observatories and the *Carnegie*.

The non-magnetic Standardizing Magnetic Observatory at Washington continued in use for the control and investigations of magnetic instruments for use in surveys and observatories. Its use was extended also to the officers of the United States Coast and Geodetic Survey in cooperative studies and improvements of such instruments. In turn the Department has had the continued privilege of access and use of the Survey's chief magnetic observatory at Cheltenham. A notable example of this cooperation is the development of the magneto-chronograph as described on page 264 by McComb (of the Survey) and Huff.

Among the instruments standardized and compared with the Department's standard-instruments, magnetometer 3 and earth inductor 48, were: Magnetometer 8, dip circles 241 and 242, and magnetograph 5 for the use of the Byrd Antarctic Expedition; magnetometer-inductor 16 for use at Huancayo; and magnetometer-inductor 25 used by Dahl in his field-work. Advantage was taken in this work chiefly by Wallis, Fisk, Green and Dahl to instruct, in the use of magnetic apparatus, Davies and Shropshire of the Byrd staff, E. R. Hand of the United States Coast and Geodetic Survey, and Gebhardt. Control-determinations of inertia and of weights for the long magnets of the various instruments and for standard magnetometer 3 were also made by Wallis.

COOPERATIVE OBSERVATORY-WORK

Apia Observatory, Western Samoa—The Department has continued cooperation throughout the year with the Apia Observatory (latitude $13^{\circ} 48'$ south, longitude $171^{\circ} 46'$ west) in Upolu, Western Samoa, as in previous years, primarily to insure maintenance of the atmospheric-electric work. The staff under the general direction of Dr. E. Marsden, Secretary of the Department of Scientific and Industrial Research of New Zealand (to which the financial and technical control of the Observatory was transferred early in 1929 from the New Zealand Department of External Affairs), consists of Director Andrew Thomson, Assistant Director C. J. Westland, and K. C. Sanderson of Auckland University College as scientific assistant (in charge of the atmospheric-electric observations), with native clerks and aids.

Throughout the year, records of atmospheric-electric potential were obtained almost unbroken at both the land-station in the Observatory grounds and at the lagoon-station erected in the shallow off-shore water inside the fringing coral-reef. Difficulties connected with the insulation of the recording instruments at the lagoon-station have been overcome so that for the first time records are unbroken for periods of a week or more. Standardization to a plane surface has been made on three occasions. The determinations showed that the change in the value of the reduction-factor was less than the limit of observation which may be taken as 2 per cent.

Hourly values of the magnetic intensity and declination have been obtained without interruption throughout the year. The winding on the

Schulze earth inductor broke down in May 1928, and it was necessary to send the instrument to the shop of the Department of Terrestrial Magnetism at Washington for overhaul. The earth inductor was practically remade by the Department, so extensive was the repair work. This was done without cost to the Apia Observatory. From September 1928, subsequent to the return of the instrument, vertical-intensity records have been secured with comparatively infrequent interruption.

The regular records of temperature, barometric pressure, humidity, sunshine, wind-force and wind-direction have been obtained without interruption throughout the year. The hourly values of each of these elements have been tabulated and the diurnal variation obtained for three seasons into which the Samoan climatic year may be divided, namely, wet, dry and equinoctial. The Dines anemometer installed in 1927 has given satisfactory service, and the wind-records secured are of use in supplementing the upper-air data.

Time was determined by solar observations made about every ten days by Westland. On account of the unvarying rate of the Observatory standard clock, the error of the time-control of the various instruments did not on any occasion exceed 0.3 second.

The determination of the lunar atmospheric tide at Apia has been completed. This investigation has been done in collaboration with Professor S. Chapman of the Imperial College of Science, London University. The computations requiring the finding of the hourly values of over 20 years of barometric records have been laborious. The effect of the moon in setting up a tide in the Earth's atmosphere has been found to be definite. The maximum tide in the atmosphere occurs about two hours after the moon passes over the meridian and amounts to about 0.004 inch.

The annual reports for 1925 and 1926 of about 90 pages each were published during the past year and distributed to a selected list of observatories and investigators. The annual report for 1927 has been set up in type and will shortly be issued. The arrears in printing the reports have been greatly reduced.

In addition to carrying on the program of observation and investigation in geophysics, further special attention has been given during the year to meteorology without any reduction in the magnetic, atmospheric-electric and seismological activities. More pilot-balloon observations were made than usual, and approximately one-third of the flights were followed to heights exceeding 10 km. The observations of this and previous years were tabulated and the results recently published in extenso.

Through the courtesy of the British Admiralty, observations were made during June and July at Atafu, the most northern atoll of the Union group and only 15 feet above sea-level. Its geographical position, 8° south of the equator at the center of the southeast trade-wind belt during June and July, makes observations there of special interest. Pilot-balloon observations made for five weeks gave unexpected results, and further observation is desired before publication. The native medical practitioner was carefully instructed in reading a barometer and other instruments; it is hoped that continuous accurate observations will now be available from the equatorial Pacific area—a vast region of which little has hitherto been known. For any aviators planning Trans-Pacific flights, weather information from these isolated island groups near the equator will be of great value.

A second station was established on Nassau Island lying several hundred miles east of Apia where Captain Williams—an exceptionally skillful observer—is in charge of the station. The comparison of observations at

Nassau and Samoa is of importance. Nassau is low and much smaller than Upolu and should, therefore, have a more truly maritime climate than Samoa. Effects due to radiation from sand have been avoided by building special instrument-shelters.

Observations have been made throughout the year at Apia on the deepness of the blue of the sky at 9^h and 15^h 30^m, the blue of the sky being matched with a series of blue-tinted cards specially prepared for this purpose by Professor F. Linke of Leipzig. The visibility of distant objects was found to be greatest when the sky was deepest blue. Also, as the sky gradually became clouded over, the fraction remaining unclouded grew whiter. The total solar radiation was measured on a large number of days on the Gorczynski pyrliometer.

The Director was transferred to the New Zealand Meteorological Service to assist for about nine months in the development of that Service in connection with the rapidly growing needs of civil and military aviation and in order to recuperate from an attack of "mu-mu," brought on by his long-continued stay in the difficult climate at Samoa—the temperate climate of New Zealand has already been extremely beneficial to him. During his absence Assistant Director Westland is serving as Acting Director with supervision of the observational program, while Thomson continues being charged with the general administration of the Observatory's program and plans.

Additional arrangements for continuation of the cooperation between the Department and the Observatory were facilitated and discussed through conferences in Washington during the visit of Secretary Marsden late in July and early in August 1928. Advantage was also taken by Thomson during his stay in New Zealand to consult with Director Skey of the Christchurch Observatory regarding the latter's potential-gradient observations begun January 1, 1928.

Tucson, United States—As a result of cooperation between the United States Coast and Geodetic Survey and the Department, the atmospheric-electric building at the Tucson Magnetic Observatory (latitude 32° 14'8" north, longitude 110° 50'1" west, elevation above sea-level 2,525 feet) of that Survey was made ready by A. K. Ludy, Observer-in-Charge there, by the end of the year. The Department had nearly completed then, in its instrument-shop, the potential-gradient and positive and negative conductivity-apparatuses of the observatory, continuous, photographic-registering type of its design similar to those in use at the Huancayo and Watheroo observatories. It is planned to install these at Tucson during September 1929, as also the necessary meteorological equipment for correlative studies. Thus the atmospheric-electric program originally contemplated at the Cheltenham Magnetic Observatory of the Survey will now be realized at a centrally located and excellently situated site. Furthermore, the location is one well suited for earth-current installations, and it is hoped such may be provided within the next year or two. Thus the observatory at Tucson will be a first-order geophysical station, the program including magnetism, atmospheric electricity, earth-currents, seismology and meteorology. The station has the further advantage of being located within a few miles of a complete installation after Petit's design for the recording and study of ultra-violet solar radiation at the Desert Sanatorium in Tucson. At the University of Arizona there are also the astronomical observatory and ample facilities to undertake later experimental laboratory investigations in geophysical problems.

REDUCTIONS OF OBSERVATORY RECORDS

Magnetic records—During the year the final reductions of the magnetograms of the Watheroo Magnetic Observatory were continued at the Office by Edmonds, while Miss Balsam has prepared the machine tabulations for direct reproduction in the next volume of the Department's *Researches*. These have been completed for the calendar year 1927 and good progress has been made on the data of 1928, the final tabulations of hourly values for declination having been finished and those for horizontal intensity and vertical intensity being well under way. Systematic methods for the routine and the summaries have been developed, permitting all phases of the office work to be kept current. In general, the scale-values for horizontal intensity and vertical intensity group themselves well, so that the factors in the formula for horizontal-intensity scale-values and the computation of P for vertical-intensity scale-values agree closely.

Green began the final office compilations for publication of the results recorded at the Huancayo Magnetic Observatory since July 1922 and made good progress.

The discussion and investigation of the magnetograph data of the two MacMillan expeditions of 1921 to 1922 and of 1923 to 1924 were continued by Wallis (see p. 275).

Electric records—An analysis of the existing scale-value data for the two conductivity-apparatuses at Watheroo for effects of temperature, relative humidity, and changes in pressure of the air was made by Wait (see p. 273). Empirical equations connecting scale-value, temperature, deflections, and operating potential were obtained by least-square methods for the period from the middle of 1924 to the middle of 1927; this work was preliminary to the final office compilations of the conductivity-records obtained at Watheroo and at Huancayo. Duvall has begun the final office compilations of the potential-gradient hourly values and means for the Watheroo series since January 1924. Other matters relating to the discussion of the atmospheric-electric data at observatories are given on pages 316–218.

INSTRUMENT-SHOP¹

The year has been marked by the completion of design and construction of the photographically recording conductivity-apparatus for use on board the *Carnegie*, the near completion of the extensive recording atmospheric-electric apparatus for the Tucson Observatory, and the development and construction in cooperation with the United States Coast and Geodetic Survey of a magneto-chronograph. The time of the shop personnel totaling about 9,800 man-hours was expended about as follows: (a) Design by Huff, completion, and testing of a recording conductivity-apparatus for the *Carnegie*; (b) design and beginning of construction of glass-blower's lathe for the experimental tube-development in applications of high voltages; (c) high-voltage apparatus; (d) atmospheric-electric apparatus for Tucson; (e) preparation of exhibits; (f) design and development of magneto-chronograph; (g) repairs and improvements to instruments for field and observatory use, buildings, laboratory and shop; and (h) stock and miscellaneous

¹ From the report of electrical engineer C. Huff, in charge of shop.

items including assembly of equipment requisitioned by the observatories and its packing for shipment.

The mechanical work on the conductivity-apparatus for the *Carnegie* was practically completed and the apparatus was under test at the end of June. The glass-blower's lathe is about 50 per cent completed. The atmospheric-electric equipment for Tucson was about 90 per cent complete. In addition to the usual annual exhibit at the Administration Building, assistance was given in the preparation of an exhibit commemorating the twenty-fifth anniversary of inauguration of the departmental scientific activities of the Institution at Cold Spring Harbor, May 31 to June 2, and to be held on the *Carnegie* in San Francisco harbor, August 26-28, 1929. The high-voltage apparatus at the annual exhibit was removed to New York and installed under Huff's direction as a permanent feature in the Museums of the Peaceful Arts.

Instrumental repairs and improvements included rearrangement of units of earth-resistivity apparatus to facilitate use in the field; fitting magnetometers 16 and 18 with earth-inductor attachments; new parts for sonic depth-finder on *Carnegie*; reconstruction of theodolites 2 and 4 damaged in the field; and alterations in the Meinesz gravity-apparatus and strengthening of its gimbal support before testing at the Coast and Geodetic Survey gravity base-station and forwarding to the *Carnegie* at San Francisco.

New designs and constructions included: An amplifier for time-signals in conjunction with gravity-apparatus; a new type of water-dropper for the *Carnegie*; six gear sets for driving recording drums; the installation of a spectrohelioscope; six new recorder-drums; and six recording lamps.

Much experimental apparatus was designed and constructed, including a dynamic-deviation device for study of effects of ship's motion on apparatus, space-charge apparatus, radio apparatus for Kennelly-Heaviside layer investigations, and high-voltage equipment.

Considerable apparatus was put in order and shipped to the Byrd Antarctic Expedition. Ionium-collectors and insulators of Department design for potential-gradient work were constructed upon request of the High Commissioner of India for use at observatories there, for the Manila Observatory of the Philippine Weather Bureau, and for the Commonwealth Solar Observatory at Canberra (Australia).

MISCELLANEOUS ACTIVITIES

International and national unions and commissions—Bauer continued as President of the Section of Terrestrial Magnetism and Electricity of the International Geodetic and Geophysical Union and as a member of the Committee on Solar Physics of the American Section of the International Astronomical Union and of the International Research Council's Committee for the Study of Solar and Terrestrial Relationships.

Breit and Peters continued as members of the American committees of the International Union of Scientific Radiotelegraphy on Atmospheric-Electric Disturbances, Variation of Radio-Wave Direction, and Cooperation. Tuve and Fleming served on Dr. Kennelly's informal Committee on Cooperation in the Cosmical Sciences.

Various members of the staff supplied information to the National Research Council as requested. Fleming was appointed a member of the International Committee on Oceanography of the Pacific to act with the Subcommittee on Physical and Chemical Oceanography.

Bauer and Fleming served as executive officers of the American Section of "Aeroarctic," the International Society for the Exploration of the Arctic Regions by Means of Aircraft. A number of our staff have been appointed members of the special commissions for the planning of the scientific work to be done in the Arctic including Bauer and Fleming, terrestrial magnetic; Ault, oceanographic; Gish and Fleming, atmospheric-electric; and Sverdrup, preparations.

Active participation has been continued by the staff in the American Geophysical Union. Bauer, Fleming and Peters served on the Executive Committee of the Union, and Fleming continued as General Secretary of the Union and until the end of the year as Secretary of the Section of Terrestrial Magnetism and Electricity, and Peters was Vice-Chairman of the Section of Oceanography through June. At the tenth annual meeting in April, Fisk was elected Secretary of the Section of Terrestrial Magnetism and Electricity and Gish as Secretary of the Section of Meteorology. The Department's researches were well represented during the tenth annual meetings of the Union and its sections. Peters spoke on the work of the *Carnegie* to date at the general-interest meeting of the Section of Oceanography on April 26, while Gish and Tuve took part April 25 in the symposium of the Section of Terrestrial Magnetism and Electricity on physical theories of magnetic and electric phenomena presenting, respectively, papers entitled "The atmospheric dynamo-theory of variations in earth-currents and terrestrial magnetism—A review" and "Echo-sounding of the Kennelly-Heaviside layer." Fleming started editing the numerous papers presented at the tenth annual meetings for publication as a volume of transactions. He also saw through the publication of the Bulletin (No. 68 of the National Research Council) containing Transactions of the Ninth Annual Meeting.

Breit continued as one of the Board of Editors of "Physical Review." Fleming, in the illness of Bauer, continued as responsible editor of the "Journal of Terrestrial Magnetism and Atmospheric Electricity."

Conferences, colloquia, lectures—The Department was well represented by papers presented during the year before the Philosophical Society of Washington, the Fourth Annual Convention of the Institute of Radio Engineers and its joint meeting with the American Section of the International Union of Scientific Radiotelegraphy at Washington in May, the American Geophysical Union at Washington in April, Brown University at Providence in October (Seiwell on oceanology), American Institute at New York in February (Breit on high-voltage apparatus and demonstration), Philadelphia Physics Club in May (Tuve on high-voltage and Kennelly-Heaviside layer work), Physics Club at University of Chicago in June (Breit on Department's work on Kennelly-Heaviside layer), the Conference of Physicists, Mathematicians, and Astronomers at Canberra, Australia, in August, the Fourth Pacific Science Congress in Java in May, and the International Congress for Oceanography, Marine Hydrography, and Continental Hydrology at Seville, Spain, in May. A lecture on the work on high voltages was presented by Tuve as one of the Institution's winter series

November 13, 1928. Breit's lectures given once every two weeks at Johns Hopkins University from January to May covered the theory of radioactive disintegration, symmetric and anti-symmetric solutions of the wave-equation, Fermi statistics, and paramagnetism of alkalis.

The weekly evening colloquium on atomic physics continued with unabated interest throughout the year. In addition, three special colloquia on quantum mechanics were arranged for by Heisenberg and Breit and were held April 18, 19 and 20, 1929, in the lecture-room of the Administration Building at Washington. The papers presented and discussed were as follows: Scattering of electrons and the continuous X-ray spectrum, by A. Sommerfeld of Munich; Unidirectional quanta, by C. Eckart of Chicago, presented by Heisenberg of Leipzig (this treatment proved essentially the same as that of Breit given about two years ago); Introduction to the quantum theory of retarded potentials, by W. Heisenberg and W. Pauli; The principle of gage invariance as applied to the Dirac equation, by H. Weyl of Zurich. All three meetings were unusually well attended and the discussion proved most fruitful. Among those engaging in the discussions were F. Hund of Leipzig and A. H. Compton of Chicago.

A winter series of biweekly meetings on theoretical aspects of terrestrial magnetism and electricity was begun October 16 and continued throughout the report-year, the meetings being held in the library of the Department's Laboratory. Members of staff of the United States Coast and Geodetic Survey, of the Naval Research Laboratory, and of the Department attended, leading the meetings and all taking active part in vigorous, helpful and constructive discussion and criticism. The following subjects will indicate the scope of these colloquia: Ultra-violet radiations as the cause of auroral displays and magnetic storms; features of magnetic storms and apparent relations between storm conditions and observed movements of Kennelly-Heaviside layer; magnetic diurnal variation and secular variation as regards seasonal and geographic distribution; relation between magnetic storms and solar conditions (Nicholson of Mount Wilson Observatory); observatory procedure; problems of secular variation; earth-currents, methods, results; diamagnetic theory of terrestrial magnetic variations; comets and magnetic storms; atmospheric electricity, methods and theories.

Exhibits—During the Institution's annual exhibit in December the Department showed exhibits as follows: (A) The production and application of high voltages in the laboratory, including working model showing principles and operation of Tesla coil to produce high voltages, diagram showing details of equipment used at the Department's laboratory in Washington to produce over 5,000,000 volts, and photographs illustrating various features of the apparatus and the work; (B) the application of the photoelectric cell to improvement of magnetic standards, developed by cooperation of the United States Coast and Geodetic Survey and the Department, including magneto-chronograph in operation to record with great precision the transits of an oscillating magnetometer-magnet across the magnetic meridian, and diagrams illustrating the principles and method of amplification used with specimen records; and (C) progress of Cruise VII of the *Carnegie*, including chart showing route of the cruise during 1928 to 1931 and portion completed in the North Atlantic from May 1 to October 11 (1928), photographs

showing observations on board during that portion of the cruise already completed, and globe showing progress of Cruise VII since beginning and relation to previous cruises.

Upon the request of the Museums of the Peaceful Arts of New York, the high-voltage exhibit was placed on indefinite loan by the Institution for exhibit in the Museums. 'Transparencies showing Department activities and equipment were prepared and provided with colored screens for use in the exercises commemorating the twenty-fifth anniversary of the Institution's inauguration of departmental scientific work.

Fleming and Rooney served on the Institution's Committee on Exhibits; Fleming was also a member of its Committee on Twenty-Fifth Anniversary Commemoration.

Library—The number of accessions during the report-year was 637, thus making 16,615 as the total number of accessioned publications June 30, 1929. As in previous years, all important articles pertaining to atmospheric electricity, polar lights, earth-currents, terrestrial magnetism, and other cosmical and geophysical subjects of present and potential interest appearing in current scientific periodicals (of which about 75 are regularly received) have been indexed and incorporated in the library card-catalogs. Experience has shown that cards indicating such articles are referred to as frequently as those representing bound volumes in the library. The checking and reclassifying of publications issued prior to 1913 and represented by cards in the old index have been completed as far as possible, only comparatively few publications remaining which it has thus far been impossible to locate, but the majority of which it is expected will ultimately be found.

A great deal of attention has been bestowed on matters incident to the publication of the "Journal of Terrestrial Magnetism and Atmospheric Electricity," particularly in editing foreign manuscripts, preparing notes of current interest, and writing reviews of outstanding publications on pertinent subjects. The practice of adding brief remarks and summaries indicative of the nature or content of the items included in the "Lists of recent publications" which have been prepared by Harradon has been continued.

A large number of letters, some at the request of the Institution, as well as numerous articles, have been translated from foreign languages. These latter deal with the latest theories regarding geophysical and cosmical relationships or descriptions of instrumental developments along the lines of interest to the Department.

A complete list of publications by members of the Department for the year ended December 31, 1928, which was published by the Institution, was prepared by Kolar; the total number of such publications since 1904 now exceeds 700. Copies of this list were mailed to all the addresses appearing on the general mailing list of the Department. As a result, requests for publications were received from all parts of the world and especially from remote localities where access to these publications was either very difficult or impossible.

The library continues to be used extensively by research workers from scientific laboratories in Washington as well as from other parts of the country. The continuance of cordial and reciprocal relations with the Library of Congress and other scientific libraries in Washington has proved

to be of mutual advantage and has contributed in no small extent to the success of the investigational work accomplished.

Publications—Reprints of the annual report prepared by Fleming for the year ending June 30, 1928, from the Institution's Year Book No. 27 were received and distributed in January. Material was supplied for several news-releases in the Institution's Press Service Bulletin. Abstracts of articles published, of papers presented before scientific societies, and of investigations under way (or completed but not published) are briefly summarized in the following pages.

ABSTRACTS OF PUBLICATIONS AND INVESTIGATIONS

The new cruise of the *Carnegie*. J. P. Ault. *Discovery*, vol. 9, 226-228 (July 1928).

Preliminary results of ocean magnetic observations on the *Carnegie* from Washington to Plymouth, Hamburg and Reykjavik, May to July 1928; from Reykjavik to Barbados to Balboa, July to October 1928; from Balboa to Easter Island to Callao, October 1928 to January 1929; from Callao to Tahiti, February to March 1929; from Tahiti to Samoa to Guam to Japan, March to June 1929. J. P. Ault. *Terr. Mag.* vol. 33, 121-128 (September 1928); 189-194 (December 1928); vol. 34, 23-31 (March 1929); 117-122 (June 1929); 249-256 (September 1929).

These articles give the preliminary magnetic results thus far obtained during Cruise VII of the *Carnegie* in the Atlantic and Pacific oceans, including tabulations showing the dates, geographic positions and observed values for the three elements, with chart-differences for the three elements determined from the latest editions of the British, German and American charts. Notes giving details of each of the passages covered follow the tabulations of results. These notes indicate generally the work done and give some account of the conditions of weather and sea encountered and of the logs.

Preliminary values of the annual changes of the magnetic elements in the North Atlantic Ocean, as determined from the *Carnegie* results, 1909-1928. J. P. Ault. *Terr. Mag.*, vol. 34, 31-34 (March 1929).

Preliminary values of the annual changes of the magnetic elements in the Caribbean Sea and the Pacific Ocean, as determined from the *Carnegie* results, 1909-1929, and from the *Galilee* results, 1905-1908 (Pacific Ocean). J. P. Ault.

These two papers summarize the preliminary values of annual changes of the magnetic elements in the North Atlantic Ocean, in the Caribbean Sea, and in the Pacific Ocean thus far determined from the *Carnegie* results of 1909-1929 and from the *Galilee* results (Pacific Ocean) of 1905-1908. In these preliminary reductions all observations are referred to the same chart, and then by comparing the resulting chart-differences the annual changes are derived; this method allows for the unlinear distribution of the element concerned over the area. (In this connection, see discussion by H. W. Fisk given in abstract on p. 253.)

The *Carnegie's* cruise in the North Atlantic. Parts I, II and III. J. P. Ault. *Carnegie Inst. Wash., Press Service Bull.*, Nos. 1-3, 12 pages (1929).

Life aboard the *Carnegie*. Parts I, II and III. J. P. Ault. *Carnegie Inst. Wash., Press Service Bull.*, Nos. 15-17, 13 pages (1929).

These news-releases of the Press Service Bulletin of the Carnegie Institution of Washington are substantially the progress-letters prepared on the *Carnegie*, describing in a popular way the work and experiences of the party on board.

Physical oceanography of the North Atlantic Ocean. J. P. Ault.

Physical oceanography of the South Pacific Ocean. J. P. Ault.

These articles are preliminary contributions on the physical oceanography from observations during Cruise VII of the *Carnegie* to Apia. They have been prepared for early publication in view of the desirability of promptly informing European and American oceanographers of the results obtained as the cruise progresses. The papers are accompanied by tabulations showing both the observed and computed values of the various oceanographic elements involved, together with a summary of observational details for each of the ocean-stations. Charts show details of temperature, salinity, density and specific-volume conditions and serve to bring out many interesting details.

Summaries are also given of the results obtained with the sonic depth-finder and particularly of new bottom-features discovered. Among these is the Carnegie Ridge located about 80 miles west of the coast of Ecuador in latitude $1^{\circ}5'$ south and longitude $82^{\circ}3'$ west; this ridge rises over 1,800 meters above the general level shown on the charts. A second ridge discovered and called Merriam Ridge is probably an extension to the northwestward of the peaks terminating in the islands of San Felix and San Ambrosio, 140 miles to the southeast; this ridge is about 10 miles across and 3,000 meters higher than the surrounding ocean-bed. An uncharted deep about 1,900 meters below the general level of the ocean-floor was found at $15^{\circ}1'$ south latitude and $98^{\circ}3'$ west longitude, and was designated Bauer Deep; the depth varied rapidly, going from 3,400 meters to 5,500 meters in a distance of 45 miles and then shoaling to 3,900 meters in 12 miles. While passing through the Tuamotu Islands and approaching and leaving Tahiti, soundings were taken to develop the profiles of Tatakoto, Amanu and Tahiti.

Bottom-samples from the South Pacific Ocean. J. P. Ault.

This is a preliminary account of the equipment and technique developed on board the *Carnegie* in the collection of bottom-samples. The snapper type of bottom-sampler as modified by J. M. Ross of the Scripps Institution of Oceanography, has been found most satisfactory.

General descriptions of the 38 samples obtained in the South Pacific during November 1, 1928, to March 11, 1929, are tabulated, together with details regarding geographic position and depth.

New data on bottom-contour of the South Pacific Ocean from soundings taken on board the *Carnegie* from October 1928 to March 1929. J. P. Ault and F. M. Soule. Beitr. Geophysik, vol. 23, 1-7 (1929).

The uncharted submarine ridges and deeps discovered by the *Carnegie* on the route between Balboa, Easter Island, Callao, Tuamotu Islands, and Tahiti are described in this paper. The methods of depth-determinations, including sonic, wire, and pressure thermometer, are briefly described.

The contour of the ocean-floor in the vicinity of several isolated peaks in the Tuamotu Group was determined, and the slopes show striking similarity. Comparison of these slopes with the theoretical slope for isolated peaks as discussed by Littlehales shows them to have smaller gradient than the theoretical except in the case of the western slope of Amanu Island. A new ridge westward from Amanu Island at $17^{\circ}7'$ south latitude and $141^{\circ}6'$ west longitude is apparently of recent origin as the bottom-sampler brought up a few fragments of black lava with no sign of ooze or mud.

Mehetia Island was shown by the soundings to be an isolated peak and not a part of the Tahitian Ridge. The slopes at Tahiti were found very similar to the western slopes of Amanu Island.

Form of the slope of Wake Island. J. P. Ault. *Beitr. Geophysik*, vol. 23, 7-8 (1929).

This is a brief account of the results obtained by soundings at intervals of every three miles while the *Carnegie* was near Wake Island—one of the most isolated peaks in the North Pacific Ocean. The profile developed is very similar to that of Midway Island both for the eastern slope and for the western.

The magnetic declination in Baltimore County. Louis A. Bauer. *Md. Geol. Surv., Baltimore Co.*, 385-392 (1929).

Annual report of the Director of the Department of Terrestrial Magnetism. Louis A. Bauer and J. A. Fleming. *Carnegie Inst. Wash. Year Book No. 27*, 1927-1928, 203-267 (1928).

This report covers the operations of the Department for the year July 1, 1927, to June 30, 1928. Following the general summary, the details of the various lines of work are briefly given under the following sub-headings: (a) Investigational and experimental work including terrestrial magnetism and electricity and cosmical relations, contributions of research associates, magnetism and atomic physics, experimental work in terrestrial electricity; (b) field-work and reductions including developments and improvements in magnetic instruments for field and observatory, ocean-work, land magnetic survey, observatory-work, instrument-work, and buildings; (c) miscellaneous activities; and (d) abstracts of publications and investigations. It is to be noted that the abstracts under (d) include not only brief accounts of published investigations and articles but also investigations, experiments, and discussions under way during the year.

The principle of uncertainty in Weyl's system. G. Breit. *Phys. Rev.*, vol. 32, 570-579 (October 1928).

Using Weyl's geometrical interpretation of quantum mechanics the fundamental relations of the transformation theory can be treated without making use of Dirac's δ function. The principle of uncertainty is particularly clear in this system. It is shown that in the discrete representation for a definite axis of the coordinate q all "Eigenwerte" of the conjugate momentum p are equally probable. It is also shown how in the limit of very fine subdivision the results of Heisenberg and Bohr are obtained. The whole treatment receives an easy interpretation by applying it to the problem of the diffraction of waves by a grating. Weyl's method of discussing quantities with continuous ranges of values is found to be equivalent to investigating diffraction phenomena in the limiting case of an infinitesimal grating space. The quantum condition $i(PQ - QP) = 1$ is shown to be correct in a purely operational sense in spite of the fact that as a matrix equation it is untrue.

The magnetic moment of the electron. G. Breit. *Nature*, vol. 122, 649 (October 27, 1928).

This note briefly discusses the hypothesis of the angular momentum and magnetic moment of the spinning electron from the viewpoint of recent work by Dirac, Darwin, Millikan, Barnett, Beck and Bates.

Shattering the atom. (G. Breit and M. A. Tuve.) *Carnegie Inst. Wash., Press Service Bull.*, No. 12, 6 pages (1928).

A news-release giving a popular account of the investigation on the production and application of high voltages in the laboratory (see p. 241 of the annual report for 1927-28).

Group-velocity and long retardations of radio echoes.¹ G. Breit. Inst. Radio Eng., Fourth Annual Convention, Tech. Program, 27-31 (May 15, 1929).

Van der Pol's hypothesis that group-velocity may account for the retardation of echoes observed by Stoermer is analyzed. It is shown that only under very special circumstances can the electron-distribution be proper. A favorable condition is obtained if the refractive index decreases exponentially with the height. It is shown that by slightly varying the electron-distribution anomalous results for skip-distances should follow. It is suggested that the echoes observed by Stoermer and van der Pol were splashes of the same echo focused accidentally on a favorable patch of ground.

The significance of observations of the phase of radio-echoes. G. Breit. Proc. Inst. Radio Eng., vol. 17, 1815-1821 (October 1929).

A method of observing the phase of radio-echoes has been developed by Tuve and Hafstad. The present note is intended to show to what extent the phase can be expected to be constant throughout the echo if the frequency-dispersion of the Kennelly-Heaviside layer is taken into account. It is shown that for reflections of 4,000-kilocycle waves with a small retardation (effective height of 200 km.) the phase can be expected to be the same for the whole echo and that in this case the observed phase is a measure of the optical path. For echoes which spend a longer time in the layer (effective height of 1,800 km.) the phase should not be constant and the average phase is not expected to be a measure of the optical path.

It is shown that by measurements on reflections with low retardation the ratio between the changes of (1) the equivalent height for interference and (2) the effective height for echo-retardation is a measure of how much of the change is due to the layer moving as a whole and how much is due to a redistribution of electron-densities through the layer. A compression or expansion of a layer having an electron-density increasing in proportion to the height above the lower boundary should give a result by the interference-method of approximately one-third the value obtained by the echo-retardations.

It is shown that the broad echoes observed at night by Hafstad and Tuve are in all probability due to multiple echoes and not to frequency-distortion in the side bands of the emitted pulses.

The effect of retardation on the interaction of two electrons. G. Breit. Phys. Rev., vol. 34, 553-573 (August 15, 1929).

The problem of describing the motion of two electrons under the influence of each other is a fairly simple one in classical particle dynamics. The electromagnetic field due to a particle in motion is readily expressed by means of retarded potentials. Darwin has succeeded in representing to a good approximation the influence of the retarded potentials by a single Hamiltonian function. The approximation used neglects terms in $(v/c)^3$ where v is the velocity of the electron and c is the velocity of light. It neglects, therefore, terms of the order of the radiation reaction on the electrons.

The present paper describes to the same approximation the interaction of electrons according to quantum mechanics and enables one, therefore, to discuss with sufficient accuracy most questions connected with the fine-structure of spectral lines. The most important forces in discussions of fine structure have been heretofore the magnetic interactions between electron-orbits and electron-spins. In addition, according to Heisenberg, the mag-

¹ Presented at the joint meeting of the Institute of Radio Engineers and the American Section of the International Union of Scientific Radiotelegraphy, Washington, May 15, 1929.

netic interaction between electron-spins is also of importance, particularly for the fine structure of helium. As a result of the calculations of this paper it became apparent that there is still another quantum force similar to that of the magnetic interactions between spins of fixed value which must be considered in addition. The effect of this force dies off less rapidly with the distance between the electrons than the ordinary spin-on-spin interaction, and the two effects are roughly of the same order of magnitude for electrons separated by ordinary atomic distances.

Meteorological program of the seventh cruise of the *Carnegie*, 1928-31. C. F. Brooks. Mon. Weather Rev., vol. 57, 194-196 (May 1929).

This paper gives an account of the meteorological work being done on the seventh cruise of the *Carnegie* with brief descriptions of the instruments and procedure.

Conductivity of observatory collector used on potential-gradient apparatus at the Watheroo Magnetic Observatory.¹ J. E. I. Cairns and G. Builder.

An abstract of this paper is given on pages 241 to 242 of the annual report for 1927-1928.

Note on the computation of the moment of inertia of a magnet and its suspension. C. R. Duvall.

It is shown, first, that the temperature- and torsion-effects may be applied to the final result of a set without any loss in accuracy. This makes it possible to omit all computation on the form on which the observations of oscillation, temperature, and torsion are recorded, with these exceptions: (1) The means of the total number of oscillations are taken, *but these means are not divided by the number of oscillations*; (2) the means of the temperatures are taken and the difference of mean temperatures without and with weight is written down for each set; (3) means of torsion-observations are taken in scale-divisions, *without reduction to minutes*; (4) the local mean times are computed. A form is arranged for the reduction of these data to the final results and an example is worked. It is found that the use of this method gives a very considerable saving of time. Next, the formula is put into shape for making the whole computation by a differential method, and the second-order terms are written down so as to be available for testing the accuracy of the method. A computing form is arranged and applied to the same example as the first form. The errors of the method are given for this example and found negligible. Attention is called to the uncertainty of such observations and numerical values are given for the series from which the example is taken. It is pointed out that the fact that the differential method may be used shows that the final result may be derived with sufficient accuracy by computing a single set, using mean times and mean temperatures. The method of the first form is preferred in that case. • If the individual sets are computed, the differential method is much to be preferred.

A note on meteorological conditions as disclosed by the *Carnegie's* observations during the West Indian hurricane of September 1928. C. C. Ennis.

The lag between solar activity and magnetic activity. H. W. Fisk. Terr. Mag., vol. 34, 147-150 (June 1929).

The question of an immediate connection between the existence of sun-spots and magnetic disturbance upon the Earth has been given much attention by investigators, notably in recent years by Chree and Bauer. The

¹ Presented for the authors by A. D. Ross at the August 1928 Conference of Physicists, Mathematicians, and Astronomers at Canberra.

present discussion has the advantage of a longer series than used by Bauer, who in 1918 was led to the conclusion from the data then at hand that the lag was greater at times of sunspot maximum than at times of minimum. When the sunspot-numbers and character-numbers are plotted, both show the period of approximately eleven years, though the character-numbers are much more irregular. The sunspot-numbers have values up to 104 on the Wolfer scale, while the mean annual magnetic character-numbers vary between 0.45 and 0.75. An empirical formula for reducing the ordinates of both curves to the same base and approximately the same amplitude was found to be $2.7 R = (C - 0.515) 10^3$, in which R is the Wolfer sunspot-number for the year and C the mean international character-number. The resulting modified numbers are subjected to a smoothing by means of an adaptation of Fourier analysis and, when plotted, form curves which are strikingly similar, the magnetic character-number curve showing a lag in phase by an amount corresponding to about one-half to three-fourths year. While it is not contended that such a lag is proven, the evidence is such as to be strongly suggestive.

A study of magnetic observations at sea to determine accidental and systematic errors and the rate of secular change. H. W. Fisk.

Discussions of secular variation from data mainly secured at land stations have indicated a complexity of this phenomenon considerably above that generally assumed in the absence of more complete knowledge. The successive cruises of the *Carnegie* and its predecessor, the *Galilee*, have provided many intersections at which values of the elements observed at different times may be compared, but a suitable method of referring such observations to the same point, and of combining them to reduce as much as possible the effect of unavoidable errors of observation, must be employed. The method used by Ault in the preparation of the preliminary tables which have been published (see p. 248), and which have sufficient accuracy of chart-making purposes, consists of referring all observations to the same chart and then comparing the resulting chart-differences. The great advantages of this method are the facility with which it can be applied and the provision which it incorporates for allowing for the unlinear distribution of the element over the area concerned. It fails, however, to use the important principle of probability involved in a least-square adjustment.

To meet this objection the following method has been applied to the analysis of many of the horizontal-intensity observations with results which appear in important respects an improvement on those of the first method, though involving considerably more labor. A segment of each course in the vicinity of the intersection can usually be taken, which forms a straight or slightly curved line. A parabolic curve is first computed through the stations along this segment, and then by means of a good chart a correction is found by which the observed value is transferred to its corresponding value on the line. In many regions and for short lines it may be assumed that the change in the element with latitude (or longitude if more advantageous) is either uniform or changes at a uniform rate. The equations then are

$$\Delta\lambda = b + x\Delta\phi + y\Delta\phi^2 \dots\dots\dots(1)$$

$$\Delta H' = b + x\Delta\phi + y\Delta\phi^2 \dots\dots\dots(2)$$

The labor involved in forming the normal-equations for the solution of the above is greatly lessened since all the products except those involving the constant terms are the same for both. The condition assumed in (2)

does not always hold for all regions, particularly in the equatorial belt, unless the very short lines are taken, in which case the number of observations that can be included in the group is so restricted that accidental errors are not sufficiently eliminated. Similar limitations are imposed when the usual equation in the form

$$\Delta H = h + x \Delta \phi + y \Delta \lambda + z \Delta \phi^2 + v \Delta \phi \Delta \lambda + w \Delta \lambda^2 \dots \dots \dots (3)$$

is used, as was possible where the track of the vessel formed a closed figure, thus providing a surface distribution which made it applicable. Analysis by these methods showed that under good conditions the residuals could be kept small, usually below 0.00050 c.g.s., particularly if privilege is exercised of rejecting observations with abnormally large residuals. Care is necessary in forming groups, and it is not safe to assume equal accuracy for all observations made aboard ship, even when no unfavorable conditions were reported.

There is evidence that systematic errors exist along certain portions of a course and that these may change with the heading of the ship or when other conditions are altered. This is in accord with the results of Peters' discussion of dynamic deviations and the effects of tilting (see p. 264). The magnitude of these errors and the frequency of their occurrence are difficult to establish from the number of places where the observations are so arranged that they may be detected. Where a track forms a narrow bow or loop, analysis of the results along the opposite arms of the figure traversed in different directions will sometimes offer important evidence. Careful analyses of the exact headings of the vessel at the times of observation indicate that systematic errors related to the general direction of the track may exist. It should be pointed out, however, that the errors, while seriously affecting the relatively small quantities from which secular changes are derived, are not of a magnitude sufficient to materially affect the general magnetic distribution.

Secular variation of magnetic intensity and its accelerations in Pacific countries.¹ H. W. Fisk.

Previous studies by the author have shown the existence of limited areas within which the rate of change of one of the magnetic elements is unusually rapid, and that these areas are not fixed in form, size or position. The investigation of the changes in annual rate and the movements of the isomagnetic lines in the immediate vicinity of these areas offers a promising approach to the study of secular variation. For example, if a system of lines be drawn through points having an equal annual rate of change for any element, these lines ("isopors") will form densely crowded, closed ovals around the centers of these areas, and these ovals undergo movements of dilation and contraction, as well as movements of translation. In the case of the horizontal-intensity isopors there is an alternation of expansion and contraction corresponding in period to the sunspot-cycle. To follow these interesting movements as closely as is desirable requires a large number of magnetic observations repeated at short intervals and well distributed throughout the area; or, much better, a sufficient number of magnetic observatories from which mean annual values for every year can be obtained. The Department of Terrestrial Magnetism has made repeat-observations over much of the western continents in sufficient number to reveal the existence of such centers and to form a general notion of their behavior,

¹ Prepared for the Fourth Pacific Science Congress in Java, May 1929; presented also before the Philosophical Society of Washington, May 25, 1929.

but these need to be followed up closely for another decade or more to verify the reality of the supposed movements.

Investigation of the secular-variation data for eastern Asia, Australia and the adjacent ocean-areas with their archipelagos, with especial reference to horizontal intensity, shows the existence of an area of rapid increase in intensity in eastern India between two areas of decreasing intensity, one in western Australia and the other centering in Siberia and extending to northern India. The study of the movement of the isopors in southeastern Asia is peculiarly favorable because of the group of observatories in China, India and the archipelagos. The contrast between the acceleration-curves found from the smoothed curves of annual changes for years 1905 to 1925 for observatories near a center of rapid change and similar curves for observatories at a distance is significant. Acceleration-curves for Sitka, Honolulu and Christchurch, remote from centers of rapid change and widely separated from each other, bear a close resemblance to sunspot-curves for the same years, that is, the accelerations are positive when the number of sunspots is greater than the mean number for all years and negative when the number is less. This does not wholly agree with the principle that the rate of change of horizontal intensity decreases as the number of sunspots increases, and vice versa. But when acceleration-curves are constructed for such observatories as Dehra Dun, Alibag, Batavia, and others in the region, this similarity to each other and to the sunspot-curve does not appear, or at best is masked by other changes not related to the sunspot-phenomenon. These differences can be accounted for by considering whether the center of rapid change moves radially toward, radially away from, or tangentially to the position of the observatory. Isopors were constructed for the epoch 1918, as that date best suited the available data from field repeat-stations. From less complete data another system was constructed for 1906, that date being chosen since both 1906 and 1918 were at or near a sunspot-maximum. During the interval the center had drifted from near Hongkong to the vicinity of Colombo, the course being such as to carry it over or very near the observatory at Toungoo, which showed a very rapid increase in annual rate until about 1912 as the center approached, after which there followed a sharp decline as it receded. A nearly constant distance from the center was apparently maintained at Barrackpore from 1904 to 1914 since the rate for those years was nearly constant. By similar reasoning the contrasting differences in the rate-curves and acceleration-curves of all the observatories can be made to harmonize.

While this movement was taking place in southeastern Asia, a similar movement was affecting the center of negative change in western Siberia, producing corresponding dissimilarities in the rate-curves for Irkutsk, Kasan and Sverdlovsk. The changes in the area of negative rate west of Australia can not be traced for lack of observations in the Indian Ocean. The interesting question is raised whether the changes thus seen to be taking place in the Eastern Hemisphere are in any way connected with those previously shown as going on in the Western Hemisphere, or whether the conditions within each area are dependent on readjustments in the interior of the Earth under the continents where they are observed to take place. The period over which precise observations have been made and the distribution of the data over the Earth's surface are insufficient at the present time to carry out the investigations as thoroughly as could be desired.

International Geodetic and Geophysical Union (actions pertaining to standards, standard instruments, and nomenclature). J. A. Fleming. *Standards Year Book*, 1929, Dept. Comm., Bur. Stan., Misc. Pub. No. 91, 36-38 (1929).

This note briefly summarizes actions of interest to standards and nomenclature as indicated by publications and meetings of national unions since the Prague Assembly of the International Geodetic and Geophysical Union in 1927.

Observations on the green flash. J. A. Fleming. *Science*, vol. 69, 298-299 (March 15, 1929).

A brief note on observations of the green flash made by F. T. Davies of the staff of the Byrd Antarctic Expedition while en route to New Zealand.

Sebastian Jacob Mauchly (1878-1928). J. A. Fleming. *Zs. Geophysik*, vol. 4, 432-433 (1928); *Nature*, vol. 123, 215 (February 9, 1929); *Met. Zs.*, vol. 46, 65-66 (February 1929).

Summary of the year's work, Department of Terrestrial Magnetism, Carnegie Institution of Washington. J. A. Fleming. *Terr. Mag.*, vol. 34, 151-153 (June 1929).

This article summarizes briefly the outstanding features of the work done by the Department of Terrestrial Magnetism during the year ending June 30, 1928, which is given in more detail in the Department's annual report for the year.

Transactions of the American Geophysical Union, ninth annual meeting, April 26 and 27, 1928, Washington, D. C. J. A. Fleming (Editor). *Bull. Nat. Research Council*, No. 68, 103 pages (1929).

American Geophysical Union. J. A. Fleming. *Beitr. Geophysik*, vol. 22, 205-207 (1929).

Progress of the *Carnegie's* seventh cruise.¹ J. A. Fleming and J. P. Ault.

Cruise VII of the *Carnegie* 1928-31 in the Pacific and Indian oceans.² J. A. Fleming and J. P. Ault.

These two papers give brief accounts of the program and route of the *Carnegie* during her present three-years' cruise which was begun May 1, 1928. The preparations for the cruise, the alterations and improvements made in the vessel and her equipment for the purpose of resuming her magnetic and electric surveys of 1909-21 and of undertaking with increased personnel a large program of oceanographic work, are described.

The papers more particularly relate to the results in physical, chemical and biological oceanography and in marine meteorology since the instruments and methods used for the magnetic and electric surveys, now so necessary for investigations of the secular variations, are described in earlier publications. The plans for the oceanographic work were adopted after discussion with leading oceanographers in America and abroad, to whose sympathetic advice and cooperation their successful development is in no small measure due. The realization of these plans has been made possible through the favorable consideration of the President, Dr. John C. Merriam, and the Trustees of the Carnegie Institution of Washington. Credit for the successful execution thus far of the program, first in the North Atlantic Ocean (May to October 1928) and since October 1928 in the Pacific, is due to the untiring interest and effort of the scientific staff of eight, supported by the sailing personnel of 17.

From consideration of the data already obtained, it is believed that this cruise will yield much valuable material to enrich many branches of geo-

¹ Prepared for the International Congress for Oceanography, Marine Hydrography, and Continental Hydrology at Seville, Spain, May 3, 1929, and presented for the authors by G. W. Littlehales.

² Prepared for the Fourth Pacific Science Congress in Java, May 1929, and presented for the authors by T. Wayland Vaughan.

physical research. It is hoped that the cruise and its results may be helpful in stimulating and may serve as a general basis for future intensive oceanographic surveys.

A gringo's visit to the Huancayo Magnetic Observatory. S. E. Forbush. West Coast Leader, Spec. Ed., Lima, Peru, 43-44 (1929).

This article is a popular account of the purpose and work of the Huancayo Magnetic Observatory.

El Instituto Carnegie de Washington. S. E. Forbush. Rev. de Marina, La Punta, vol. 14, 1-12 (January-February 1929).

El Observatorio Magnético de Huancayo. S. E. Forbush. Rev. de Marina, La Punta, vol. 14, 89-107 (March-April 1929).

The first of these papers gives accounts of the foundation of the Carnegie Institution of Washington and of its several departments of scientific research with general descriptions of equipment. The second paper deals with the equipment, program and purposes of the Huancayo Magnetic Observatory and of the Department of Terrestrial Magnetism under the auspices of which it is operated. Specimens of magnetic records of the Earth's magnetism and of records of atmospheric electricity are reproduced.

An experimental test of Schrödinger's theory. E. Gaviola. Nature, vol. 122, 772 (November 17, 1928).

According to Schrödinger's theory, the intensity of an expectral line in emission is not determined by the number of atoms in the higher level and the coefficient of expontaneous emission, but by the populations of both the higher and the lower levels corresponding to that line. If we have then two lines emitted by the same higher level, their relative intensity ought to change if we change the relative population of the lower levels, and, furthermore, the change in the relative intensity of the lines should be equal to the change of the relative populations.

This conclusion has been tested experimentally. The result for the case treated is in contradiction with the common interpretation of Schrödinger's theory.

The power relation of the intensities of the lines in the optical excitation of mercury: Theory I. E. Gaviola. Phil. Mag., vol. 6, 1154-1167 (December 1928).

The influence of foreign gases on the optical excitation of mercury: Theory II. E. Gaviola. Phil. Mag., vol. 6, 1167-1191 (December 1928).

The efficiency of quenching collisions and the radius of the excited mercury atom. E. Gaviola. Phys. Rev., vol. 33, 309-318 (March 1929).

The evidence in favor of and against the assumption of Foote that every collision of a foreign gas molecule with an excited mercury atom is sufficient in quenching the resonance radiation is discussed, and a new calculation of the efficiency of collisions is given, based on Stuart's measurements, which shows that the efficiency can be assumed to be equal to one in the case of CO, H₂, and perhaps O₂, but that it is undoubtedly smaller than one for H₂O, N₂, A, and He. CO has actually a greater quenching efficiency than H₂. The *radius of the excited mercury atom* is calculated, using an improved value for the amount of resonance-radiation re-absorbed in the resonance vessel and found to be $r_{Hg'} = 5.5 \times 10^{-8}$ cm. or threefold normal for the case of CO. The apparent higher quenching efficiency of oxygen than hydrogen is explained by the partial oxidation of the mercury vapor and consequent decrease of the density of the last. It is shown that the *life of metastable atoms* increases with the admission of certain foreign gases into the fluorescence vessel. (See p. 258 for further remarks on this paper.)

A principle of duality and the causal law. E. Gaviola. *Nature*, vol. 123, 604 (April 20, 1929).

The possibility of a causal space-time description of experience has recently been often denied, and emphasis has been laid upon the purely statistical validity of quantum-theoretical relations. This denial of a possible causal space-time description has aroused suspicions and diffidence in regard to the newer physics. The purpose of this note is to show that there is no need for the above denial and that we have not only one possibility of a causal space-time description of experience, but actually two of them. This superabundance of possibilities of description is the very reason why some relations can have only statistical validity.

Photosensitized band fluorescence of OH, HgH, NH, H₂O, and NH₃ molecules. E. Gaviola and R. W. Wood. *Phil. Mag.*, vol. 6, 1191-1210 (December 1928).

On time-lags in fluorescence in the Kerr- and Faraday-effects. E. Gaviola. *Phys. Rev.*, vol. 33, 1023-1034 (June 1929).

A critical study of the experimental literature is made in regard to the existence of time-lags or "dark-times" in fluorescence, and it is found that not a single experiment shows the existence of such things. Moreover, experiments seem to show that in all the cases when the emitting state is the state reached directly as a result of the excitation process, the emission begins immediately upon excitation and decreases exponentially. Experiments interpreted as showing the existence of time-lags in the Kerr- and Faraday-effects are also considered, and it is found that they do not prove the reality of such time-lags. An analysis is made of the way in which the "optical shutter" of Beams works, with the result that it is found to behave quite differently from what it was supposed to do. Wave-trains of light, that were supposed to be cut off by it in parts of 3-cm. length, are certainly not reduced to less than 300 cm., or 100 times more than assumed.

Remarks on "The efficiency of quenching collisions and the radius of the excited mercury atom." E. Gaviola.

It is shown that the interpretation given to the reabsorption-factor f in the previous publication¹ (see p. 257) was erroneous. An improved and general treatment of reabsorption is given, using which the radius of the excited mercury atom turns out to be 3.4Å for hydrogen and 5.7Å for CO collisions. The efficiencies of collisions with other gases are 0.4 for H₂O, 0.2 for N₂, 0.05 for A, and 0.005 for He.

On life and concentration of metastable atoms and the quenching of mercury resonance-radiation. E. Gaviola.

A complete and general study of the dependence of life and concentration of metastable mercury atoms, optically excited, on experimental conditions, on foreign gas-pressures, and on intensity of illumination is given. This study explains why the life can not be larger than 10^{-2} second under laboratory conditions and why foreign gases act so differently in regard to the accumulation of excited atoms. The theoretical results are in good agreement with all experimental data available. An improved and more general formula for the quenching of mercury resonance-radiation is obtained. The efficiencies of collisions of the second kind of metastable mercury atoms with N₂, A, and He molecules are calculated numerically. It is shown that the concentration of metastable atoms increases only with the square root of the intensity of the exciting light, and not with the exciting light itself as is generally assumed.

¹ See *Phys. Rev.*, vol. 33, 309-318. March 1929.

The new measurement of the velocity of light and the constancy of the time-unit
E. Gaviola.

On occasion of the new measurement of the velocity of light made in Germany by Karolus and Mittelstaedt using the method proposed by Gaviola three years ago (undamped controlled Kerr cells instead of the tooth-wheel of Fizeau), in which they obtained a precision comparable with Michelson's, using a mirror-distance of only 40 meters, the author suggests that precision measurements of the velocity of light can be used for controlling the constancy of the time-unit. A chronological comparison of all the previous measurements shows that the velocity of light seems to decrease steadily by 2 or maybe 3.5 km. per second each year. If this be true, this would mean that the length of the day shortens as much as 0.6 or 1.0 second every year.

Sebastian Jacob Mauchly. O. H. Gish. Beitr. Geophysik, vol. 22, 1-2 (1929).

Sebastian Jacob Mauchly, 1878-1928. O. H. Gish. Terr. Mag., vol. 34, 77-80 (March 1929).

These obituaries give accounts of the scientific work of Sebastian Jacob Mauchly. The second paper is accompanied by a list of Mauchly's scientific publications prepared by H. D. Harradon.

A new potential multiplier. O. H. Gish.

In the apparatus used on the *Carnegie* for collecting the radioactive content of the air, a means of maintaining a high potential is required. Heretofore a Kelvin water-dropper multiplier has been used. In this the drops falling from the tips of seven capillary tubes were charged by induction. These drops, after breaking away from the tubes, were collected in a receptacle which thus became charged to an adequate potential. However, the capillary tubes were rather difficult to adjust and maintain. In the hope of eliminating this irksome feature a new multiplier, using a single atomizer instead of the several capillary tubes, was designed. The design is such that the insulation of the collecting receptacle is well shielded from the spray of the atomizer and the whole is so enclosed as to prevent this spray from fouling other insulators. During extended tests in the laboratory this multiplier developed a potential of about 5,000 volts, and on short-circuit a current of 0.25 microampere was registered, which is about tenfold the current obtained with the seven-point dropper.

Constants of nature in terrestrial electricity.¹ O. H. Gish. J. Wash. Acad. Sci., vol. 19, 87 (February 19, 1929).

Those values in earth-currents, earth-resistivity and atmospheric electricity, which for some purposes may be considered constants, were presented and their significance and reliability briefly discussed.

The atmospheric dynamo-theory of variations in earth-currents and terrestrial magnetism—
A review.² O. H. Gish.

The atmospheric dynamo-theory maintains: That the atmosphere at a height from 100 to 170 km. is a relatively good conductor, equivalent to a sheet of copper 1/10 mm. thick directly under the sun; that motion of this relative to the Earth's permanent magnetic field due to winds arising from tidal and other forces generates electric currents in this region of the atmosphere; that the magnetic field of these primary currents together with that

¹ Notes read in a symposium before the Philosophical Society of Washington, October 13, 1928.

² Presented at the meeting of the Section of Terrestrial Magnetism and Electricity of the American Geophysical Union, Washington, April 25, 1929.

of the secondary currents induced in the Earth by variations in the former constitutes the observed fluctuations of the Earth's magnetism, except those of very long-period (secular variations) and some short-period fluctuations (local disturbances) which appear only over small areas. This theory was briefly outlined and its tenability considered.

Characteristics of earth-currents at the Huancayo Magnetic Observatory for the year 1927. O. H. Gish and W. J. Rooney.

The mean diurnal-variation in earth-current potentials at the Huancayo Magnetic Observatory for the year 1927 is characterized by an outstanding principal maximum and an equally prominent principal minimum. The diurnal variation of the eastward component is nearly the inverse variation of the northward component. The principal maximum of the northward component occurs at 9^h, while the principal minimum in the northward and the principal maximum of the eastward component both occur at 14^h5. Two minor maxima and minima are in evidence, but these are relatively small.

There are at this Observatory two independent systems of electrodes so that two independent values are obtained both for the northward and for the eastward components. That which is designated as system I is situated on a flat shelf of land which is elevated only slightly above the level valley of the Mantaro River. The other, system III, is located on a shelf about 300 feet higher than that of system I. The mean diurnal-variation of corresponding components for the two independent systems are in very close phase agreement but the amplitudes differ considerably. For system III the range in the mean diurnal-variation of the northward component is 12 per cent greater than that of the eastward component, and the eastward component of system III is 75 per cent greater than the corresponding component of system I. Furthermore, a systematic variation in this relation occurs during the year. The ranges for system I are for northward component 3.12 mv/km. and for eastward component 3.29 mv/km. At present this disparity is tentatively considered due to the combined effect of differences in the resistivity of the two regions and in the topography. The variation of daily range during the year has exactly the same character in all components. Two maxima occur, one at each equinox, and one minimum is observed in June and another in January or February.

A leak-free method of measuring air-potentials. O. H. Gish and K. L. Sherman. *Terr. Mag.*, vol. 34, 231-237 (September 1929).

This method, which was developed to eliminate some uncertainties in the measurements of air-potentials, has the following advantages: (a) No errors, arising from the most likely defects in insulation, enter the measurements even under conditions that would necessitate temporary abandonment of observation with the usual methods; (b) the air-potentials are read directly in volts from a voltmeter; (c) the electrostatic instrument requires no calibration, and the desired checks of its constancy can be readily made at any time during the measurements, with no appreciable delay.

The equipment used in most of the measurements thus far comprises a Simpson stretched-wire collector-system with insulators provided with guard-rings, a Wulf-type bifilar electrometer, a voltmeter with 300-volt range, and a slide-wire rheostat which may be used as a potential divider.

An auxiliary potential sufficient to deflect the fibers to a sensitive part of their range when they are earthed is applied to the inner case of the electrometer. The auxiliary-potential batteries and the outer case of the electrometer are insulated from earth by ordinary insulators and the outer

case is connected with the movable contactor of the slide-wire rheostat and with the guard-rings on the insulators. A battery, with an e.m.f. large enough to cover the range of potentials to be measured, is connected across the slide-wire, one end of which is earthed and connected through the voltmeter to the outer case of the electrometer. To obtain a measurement, the movable contactor is moved in such a way as to bring the fibers to their zero-position. With this adjustment made, the guard-rings and outer case of the electrometer are at the same potential as the fibers, and this can be read directly from the voltmeter. When this adjustment is maintained, there is obviously no transport of charge across the insulators of the collector-system. This arrangement, as thus far used, necessitated no changes in any of the instruments. However, in view of the fact that the electrometer is on occasions at a fairly high potential, the observer may receive a shock while making the readings. On this account it is desirable that the end of the eyepiece be covered with an insulating sleeve.

Continuous registration of the electric charge of air. O. H. Gish and K. L. Sherman.

Apparatus for obtaining continuous records of the electric charge of air was developed and operated during the months of October and November 1928. The design is a modification of Obolensky's method. The Faraday cage is connected to earth through a radioactive cell whose resistance is about 1.5 E.S.U., and the quadrants of the electrometer are connected to the terminals of this high resistance. The charge that is given up to the Faraday cage by the air, which is aspirated through it, gives rise to a minute current through the high resistance and causes a deflection of the electrometer needle which is approximately proportional to the *ir* drop across the high resistance. This arrangement is calibrated in terms of current by means of the device used at the observatories of the Department for calibrating the conductivity-recorder.

The hourly means from records for eleven complete days in November showed a principal maximum at 9^h and a secondary maximum at about 20^h local mean time. The value of the principal maximum was +0.16 E.S.U. per cubic meter, and that of the principal minimum was +0.09 E.S.U. per cubic meter. The mean of 132 hours of registration during November was +0.13 E.S.U. per cubic meter. Although the hourly means for the eleven days in November were all positive, yet some negative charge was recorded. In 38 days during October and November, negative space-charge was recorded 6 per cent of the time. For a considerable part of these earlier records the control was insufficient to establish the magnitude, although the sign could be definitely ascertained. It appeared that, in addition to occurring less frequently, the average negative charge was smaller and more variable than the positive. The largest negative value recorded was -0.2 E.S.U. per cubic meter. It is planned to continue registration of this element when a suitable air-turbine is procured.

Potential gradient and conductivity at Washington, D. C. O. H. Gish and K. L. Sherman.

Registration of the potential gradient of the atmosphere was begun in the deck-observatory on the roof of the laboratory at Washington in February 1917, and has been continued with only slight interruption ever since, thus completing twelve years of continuous record in February 1929. The variations in the reduction-factors as determined at intervals over this period are of such a character as to raise doubts about the reliability of the factors during the earlier half of the period. Further consideration of this matter is necessary before the final reduction of the recorded deflections to volts per meter can be made.

In this preliminary study monthly means of the recorded potentials have been examined. These show very definitely an annual variation with a maximum occurring usually in December and a minimum in July. The mean of the winter maximum for the eleven years is 215 volts, and the mean of the summer minimum is 102 volts. If the average reduction-factor is applied to these values to reduce them to volts per meter, they will be increased by some 5 to 10 per cent. A comparison of the secular variation in Wolfer sunspot-numbers and that in the recorded potentials shows a general correlation but with large departures. While the sunspot-minimum occurred in 1923, that in the potentials occurred in 1924 or 1925.

In addition to the air-potential registrations carried on, the measurement of the conductivity of the atmosphere was begun in January 1919. Positive conductivity was recorded during the first two years, but since June 1921 negative conductivity has been recorded. Examination of the recorded monthly mean deflections shows that this element is roughly in opposite phase to that of the air-potentials. Close control of the apparatus has not been maintained throughout the period, so that the data may not admit of accurate quantitative analysis. Preliminary computations, however, indicate an average value for negative conductivity of about 0.18×10^{-4} E.S.U., a value much lower than that obtained at many other places.

Note on Kennelly-Heaviside layer observations during a magnetic storm. L. R. Hafstad and M. A. Tuve. *Terr. Mag.*, vol. 34, 39-44 (March 1929).

Observations of the Kennelly-Heaviside layer by the echo-method during the magnetic disturbance of October 17-19, 1928, showed an unusually great effective height and a change in echo-pattern. Brief description is given of the method and of the results obtained on undisturbed days, which are compared with those obtained during the disturbance. The marked changes observed make it clear that further records of this kind will be of great interest.

Studies of the height of the Kennelly-Heaviside layer by the echo-method.¹ L. R. Hafstad and M. A. Tuve. *Inst. Radio Eng., Fourth Annual Convention, Tech. Program*, 32 (May 15, 1929).

Further studies of the Kennelly-Heaviside layer by the echo-method. L. R. Hafstad and M. A. Tuve. *Proc. Inst. Radio Eng.*, vol. 17, 1513-1522 (September 1929).

Recent observations of the Kennelly-Heaviside layer by the echo-method are described. Multivibrator-modulation was used, giving extremely sharp "peaks" on 4,435 and 8,870 kilocycles. Practically all of the observations were made on the former frequency, as 8,870 kilocycles skipped over the receiver, which was very near the transmitter. Two 24-hour series of observations showed a marked diurnal-variation in the effective height of the layer and in the echo-pattern received for each transmitted "peak." The echo-pattern shows multiplicities during the day and evening, but becomes very complex at night. A few observations made during the magnetic disturbance of October 17-19, 1928, showed an unusually great effective height and a change in the echo-pattern. Daytime heights for a number of days during the autumn of 1928 are given.

¹ Presented at the joint meeting of the Institute of Radio Engineers and the American Section of the International Union of Scientific Radiotelegraphy, Washington, May 15, 1929.

An echo-interference method for the study of radio-wave paths.¹ L. R. Hafstad and M. A. Tuve. *Proc. Inst. Radio Eng.*, vol. 17, 1786-1792 (October 1929).

An experimental determination of the rate of change of radio-frequency phase of the separate downcoming echoes has been carried out. The small-power crystal-controlled oscillator circuit of the 4,435-kilocycle transmitter operates continuously, the high-power pulse transmission being produced by modulating the power-amplifier circuits. A receiver was operated very near the transmitter, having rapid recovery from the paralyzing effect of the pulse ground-wave and sufficient sensitivity to receive the echoes with good amplitude, and having a very slight coupling to the crystal oscillator-circuit, such that the crystal "pick-up" was comparable to the echoes received. The echoes showed their changing radio-frequency phase by alternately adding to and subtracting from the constant crystal oscillator pick-up. This "interferometer" is naturally sensitive to small changes in the optical path of the waves. The phase-changes are regular, but the time of one 360° phase-change on 4,435 kilocycles varies from 1 second to 60 seconds, or possibly longer during the day and evening, and at times changes between these limits in as short a time as 15 minutes. When multiple echoes are present, the second and third echoes phase in and out more rapidly than the first echo, but not by an even factor.

List of recent publications. H. D. Harradon. *Terr. Mag.*, vol. 33, 180-184 (September 1928); 263-270 (December 1928); vol. 34, 87-92 (March 1929); 168-172 (June 1929).

This list is a bibliography of current literature relating to (A) terrestrial and cosmical magnetism, (B) terrestrial and cosmical electricity, and (C) miscellaneous subjects allied to (A) and (B). In many cases, for the more important publications, the compiler has prepared brief abstracts which are included with the references.

Remarkable auroral display of July 7 to 8, 1928. H. D. Harradon. *Terr. Mag.*, vol. 33, 167-168 (September 1928).

A summary of communications received giving details of this remarkable auroral display on land and sea. The report covers observations at stations in the area from Maine to Texas and from Michigan to 100 miles east of Boston.

Principal magnetic storms recorded at the Watheroo Magnetic Observatory: April to May 1928; July 1928; October to December 1928; January to May 1929. H. F. Johnston. *Terr. Mag.*, vol. 33, 170 (September 1928); 259 (December 1928); vol. 34, 161 (June 1929); 263 (September 1929).

Redetermination of reduction-factor at Watheroo for use with atmospheric potential-gradient records.² H. F. Johnston and F. W. Wood.

An abstract of the essential parts of this paper is given on pages 258 to 260 of last year's annual report; some additional data were included for the conference at Canberra.

List of publications of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, 1928. J. J. Kolar. *Carnegie Inst. Wash.*, 9 pages (December 31, 1928).

This list contains titles of some 88 papers and contributions to scientific societies and magazines and of annual report published during the calendar

¹ Presented at the meeting of the Section of Terrestrial Magnetism and Electricity of the American Geophysical Union, Washington, April 25, 1929, and at the joint meeting of the Institute of Radio Engineers and the American Section of the International Union of Scientific Radiotelegraphy, Washington, May 15, 1929.

² Presented for the authors by Dr. A. D. Ross at the August 1928 Conference of Physicists, Mathematicians, and Astronomers at Canberra.

year 1928 on magnetic, electric and oceanographic results by members of the staff of the Department. It is in continuation of a similar list for publications during 1904 to 1927.

Principal magnetic storms recorded at the Huancayo Magnetic Observatory: May to July 1928; August to September 1928; October 1928; November 1928 to February 1929; March to April 1929. P. G. Ledig. *Terr. Mag.*, vol. 33, 171 (September 1928); 260-261 (December 1928); vol. 34, 82-83 (March 1929); 159-160 (June 1929); 262 (September 1929).

The magneto-chronograph and its application to magnetic measurements.¹ H. E. McComb and C. Huff. *Terr. Mag.*, vol. 34, 123-142 (June 1929).

The period of a magnet oscillating under the directive force of the Earth's magnetic field is a function of the strength of that field. Heretofore the estimation of the period has been accomplished by eye-and-ear readings, but in the present method the personal equation is entirely eliminated. Light from an intense source, such as an automobile headlight-lamps, is condensed on the glass-scale end of a magnetometer-magnet and after reflection is focused on a slit in front of a photo-electric cell. The reflected beam acts as an optical lever whose period is the same as that of the magnet but whose amplitude is twice as great. At each transit of the image across the slit, current is passed by the cell and, after passing through amplifiers, is made to operate a pen on a chronograph. A chronometer in the circuit marks seconds on the record by the same pen. In this investigation the method was applied in the determination of the moment of inertia of a magnetometer-magnet, estimation of personal equation in eye-and-ear readings, and in preliminary tests of the relative absolute magnetometer.

The production and manipulation of quartz filaments for electrometers and galvanometers.² H. E. McComb.

The special apparatus described in this paper was designed and made by the Department of Terrestrial Magnetism. The technique of production and manipulation of the filaments applies principally to the smaller filaments as used in electrometers and galvanometers.

The constants of nature in terrestrial magnetism.³ W. J. Peters. (Abstract) *J. Wash. Acad. Sci.*, vol. 19, 87 (February 19, 1929).

As a geophysical term the word "constants" is used in terrestrial magnetism to denote the slowly changing quantities that occur in formulæ for the distribution or changes in the distribution of magnetism of the Earth. This paper presents briefly these constants as at present determined by magnetic surveys and mathematical discussion and investigation of such data.

Compass and dip-circle deviations caused by harmonic motion.⁴ W. J. Peters. (Abstract) *J. Wash. Acad. Sci.*, vol. 19, 202-204 (May 19, 1929).

Tilting deviations in magnetic declinations. W. J. Peters. *Terr. Mag.*, vol. 34, 93-115 (June 1929).

These two papers report on experiments made by swinging compasses in a wooden swing for the purpose of investigating deviations caused by the

¹ This research is one done cooperatively by the United States Coast and Geodetic Survey and the Department of Terrestrial Magnetism.

² This report is based upon cooperative work between the United States Coast and Geodetic Survey and the Department by the author at the Department's laboratory in Washington with the assistance of K. L. Sherman and O. H. Gish.

³ Notes read in a symposium before the Philosophical Society of Washington, October 13, 1928.

⁴ Prepared for the International Congress of Oceanography, Marine Hydrography, and Continental Hydrology at Seville, Spain, May 3, 1929, and presented for the author by G. W. Littlehales. This paper was also presented before the Philosophical Society of Washington, March 16, 1929.

ship's rolling motion. Results obtained with various types of compasses are submitted in two tables. Dynamic deviations, the kinetic equilibrium-error, and conditions other than those considered in these two theories are briefly discussed. Equations are given for computing the direction and relative strength of the apparent gravitational field as affected by the accelerations of the rolling motion. These are used to determine the maximum angle of tilt produced by the maximum angle of roll. The kinetic equilibrium-error for an angle of tilt in one direction is shown to be different for an equal angle of tilt in the opposite direction for certain elements in certain directions of the axis of tilting, and hence gives rise to deviations. Examples are given for the three magnetic elements for instantaneous values of tilting. The computed deviation in declination that results in the case of a magnet having large moment of inertia, constrained to move about an axle parallel to the radius of swing, and having considerable damping has been found to be much smaller than would be indicated by the results of the experiments for the same conditions. It is concluded that this theory of tilting deviations does not account for the whole deviation observed and must be regarded as only contributing a part of the effect as does also the theory of dynamic deviations.

Work of the *Carnegie* to date.¹ W. J. Peters.

The first year of the *Carnegie's* seventh cruise. W. J. Peters. Sci. Mon., vol. 29, 97-108 (August 1929).

Brief accounts are given of the program and route of the *Carnegie* during the first year of the seventh cruise which began May 1, 1928.

The principal object of the magnetic work has been restricted mainly to the determination of secular variation. The atmospheric-electric observations are even more extensive than on earlier cruises, since this work had been inaugurated very much later than the magnetic. The papers go more into detail in describing observations and records of other ocean studies, physical, chemical and biological.

Practically one-quarter of the 110,000 nautical miles of cruising planned was completed in the first year. The passage of 12,700 miles in the Atlantic Ocean was completed during May to October 1928; leaving the Canal Zone at the end of October 1928, the first passages totaling about an equal distance in the southeastern Pacific Ocean had been completed upon arrival April 6 at Apia, Western Samoa.

Aurora and low-frequency radio reception, July 7 to 8, 1928. G. W. Pickard. Terr. Mag., vol. 33, 168 (September 1928).

This brief note points out a change over normal low-frequency radio reception at Newton Centre, Massachusetts, from Schenectady and Pittsburgh which apparently is associated with the aurora of July 7 to 8, 1928.

Concerning lunar effects on electromagnetic waves. G. W. Pickard. QST, vol. 12, 20 (August 1928).

The author concludes on the basis of continuous records extending over more than two years of night-reception in the broadcast band, as well as from a consideration of the relative effects exerted by other cosmical agencies, that moonlight, regardless of intensity or degree of polarization, can have no measurable effect on radio transmission.

¹ Presented before the meeting of the Section of Oceanography of the American Geophysical Union, Washington, April 26, 1929.

The use of resistivity-measurements in the detection of mineralized areas. W. J. Rooney.

Since the possibility of finding certain types of discontinuity in sub-surface geological structures by means of surface measurements of earth-resistivity had become manifest in some four years' work with the earth-resistivity meter developed in the Department, this method was selected by the United States Bureau of Mines as one of those to be tried in certain mineralized regions during the summer of 1928. Through a cooperative arrangement between the Bureau of Mines and the Carnegie Institution, surveys were made at the three following sites: (a) Baltimore, Maryland, surface-structure serpentine with scattered deposits of chromite; (b) Mineville, New York, igneous rock with deep-lying magnetite bodies; (c) Cornwall, Pennsylvania, complex structure, overburden varying from dry drift-material to marshy humus-bearing soil and ranging in thickness from zero to 100 or more feet. The substructure at Cornwall between the overburden and the magnetite ore-body was made up of sandstones, quartzites, conglomerates and limestones, very inhomogeneous and irregular in form, and ranging in thickness from 70 to 400 feet. The ore-body itself had a considerable dip and ranged from 40 to 100 feet in thickness.

At one of the eight survey-areas of the first site the possibility of chromite at a depth of 20 feet was indicated. However, sampling at one point on this area with a churn drill disclosed no considerable quantity of chromite. The sampling indicated that the observed effect was due rather to the alterations in the serpentine down to about 20 feet. The resistivity of serpentine at this site ranged from 35,000 to 65,000 ohm-cm.

Surveys over a large magnetite body at the second site indicated that where deepest the top of the ore-body was at a depth of about 700 feet and the bottom at about 900 feet. A dip was also indicated. These results and those of other surveys at this site where the ore-bodies were nearer the surface checked well with the drill-records.

The results obtained at the third site are of such a nature that they can not be briefly abstracted. In general, the agreement with the drill-records was not so good as at the second site. Certain puzzling departures from previous experience were found here. These suggest that the main structure is not isotropic in the horizontal plane. Measurements in pits at this site on large outcrops of magnetite gave values of resistivity ranging from about 100 to nearly 1,000 ohm-cm. The former probably represents the unaltered ore.

Two new species of commensal copepods from the Woods Hole region. H. R. Seiwell. *Proc. Nat. Mus.*, vol. 73, 5 (1928).

Phosphate-content and hydrogen-ion concentration of the surface water of the English Channel and Southern North Sea, June 18-22, 1928. H. R. Seiwell. *Nature*, vol. 122, 921-922 (December 15, 1928).

This is a short note giving with a graph the results obtained on the *Carnegie* June 18 to 22, 1928. It illustrates the relation between phosphate-content, hydrogen-ion concentration, and change in daylight-interval for the group of stations in English Channel, Straits of Dover and North Sea during the period of observation.

The phosphate-content of the North Atlantic Ocean. H. R. Seiwell.

This preliminary report, illustrated with graphs to visualize the data, discusses the results obtained and analyses made on the *Carnegie* in the North Atlantic Ocean during July 28 to September 15, 1928, under the following headings: Methods; some general considerations of the vertical and hori-

zontal distribution of inorganic phosphates in the area surveyed; the upper phosphate-layer; the intermediate phosphate-layer; the lower phosphate-layer; the chemical fertility of the photic region of plant activity; and summary. The discussion indicates that the character of phosphate-distribution in the North Atlantic is dependent chiefly on the physical factors controlling circulation and that, on the whole, this distribution is such as to divide the area investigated into three main categories, each subject to a different set of physical conditions.

Procedure of preliminary examinations of *Carnegie* bottom-samples. H. R. Seiwel.

This is a summary detailing procedure followed aboard the *Carnegie* in preliminary examinations, physical and chemical, of bottom-samples obtained during November 1928 to March 1929. Preliminary descriptions of each of the 38 samples obtained during the five months give geographic position; depth; type (with comparison of type as given by Murray); physical characters of wet and dry samples; microscopic characters of whole sample, coarse separate, fine washings, and of residue after acid treatment; action in hydrochloric-acid treatment; and remarks.

Referat über den Plan und die Arbeiten der Carnegie Expedition (VII Kreuzfahrt). H. U. Sverdrup. (Abstract) *Naturwissenschaften*, vol. 15, 590 (July 27, 1928).

A short statement of the equipment and program for Cruise VII of the *Carnegie*.

On the importance of auroral photographs taken from one station. H. U. Sverdrup. *Terr. Mag.*, vol. 33, 198-202 (December 1928).

The author deems it pertinent, in view of wide interest and development in scientific research on aurora, to call attention to some problems, the study of which can be advanced by taking photographs from one station. The discussions of results on the *Maud* Expedition have proved the value of such work where it is not possible to obtain simultaneous photographs at stations 20 to 30 km. apart.

The centennial celebration of the Gesellschaft für Erdkunde zu Berlin and the oceanographic conference, May 24 to 26, 1928. H. U. Sverdrup.

The author reports as delegate of the Carnegie Institution of Washington to the celebration.

Report on magnetic storm of July 7 and 8, 1928, as recorded at the Apia Observatory. A. Thomson and C. J. Westland. *Terr. Mag.*, vol. 33, 168-169 (September 1928).

Report on the Apia Observatory, Western Samoa, for 1926. A. Thomson. Wellington, W. A. G. Skinner, Govt. Printer, 96 (1929).

This report contains, in addition to the magnetic, seismic and meteorological data resulting from records at the Observatory for 1926, those of atmospheric potential-gradient obtained with the cooperation of the Department.

Echo-sounding of the Kennelly-Heaviside layer.¹ M. A. Tuve.

Observations of the Kennelly-Heaviside layer have been continued at the Department by the writer and L. R. Hafstad. The United States Naval Research Laboratory, as before, has kindly transmitted the necessary schedules of signals. Multivibrator modulation was used, giving very sharp

¹ Presented at the meeting of the Section of Terrestrial Magnetism and Electricity of the American Geophysical Union, Washington, April 25, 1929.

pulse-signals on 4,435 and 8,870 kilocycles. A marked diurnal-variation in the effective height of the layer and in the echo-pattern received for each transmitted pulse or "peak" was observed in three 24-hour series of observations taken during the early fall and winter. The echo-pattern shows multiplicities during the day and evening but becomes very complex at night.

Following a suggestion of Breit, an experimental determination of the rate of change of radio-frequency phase of the separate downcoming echoes has been carried out as described elsewhere (see p. 263).

High voltage—Its relation to studies of the structure of matter.¹ M. A. Tuve.

Modern physics has demonstrated the electrical nature of matter. Each atom comprises a positively charged nucleus surrounded by a negative "electronic structure." The stray electric fields external to the atom due to this electronic structure cause chemical combination—energy-equivalents, fractions of a volt; energy-changes of the outer electrons produce lines in the visible spectrum—energy-equivalents, a few volts; energy-changes of inner electrons produce X-rays—characteristic energy-equivalents, up to 100,000 volts. Radioactivity is a phenomenon of change in the nucleus, and the usual equivalent energy involved is several million volts.

To break up the atomic nucleus for the study of its structure, bombarding particles must be obtained with energy-equivalents of millions of volts. The natural rays of radium have been used for this purpose by Sir Ernest Rutherford and others. An artificial and controllable source of similar rays, which could be made much more powerful than any available radium source, would be a vacuum tube with several million volts across its terminals.

The work done at the Department on the problem of producing such an artificial source was described. The familiar "Tesla coil" has been developed as a source of extremely high voltages—up to 5,000,000 volts—and progress has been made on the experimental design of vacuum tubes to withstand such voltages.

The measurement of condensation nuclei with an Aitken counter. G. R. Wait.

There is lack of agreement among observers regarding the proper method for computing the number of nuclei per cubic centimeter in the air from data obtained by means of an Aitken counter. After admitting each new supply of dusty air into the receiver, several expansions with the pump are usually required to bring down all the particles. Some observers² maintain that not only the nuclei falling on the first expansion but also those falling on the succeeding expansions should be counted. Other observers³ believe that only those falling during the first expansion should be included in the count.

Tichanowsky² states that the particles falling in the second and succeeding expansions are the ones that failed to reach the counting stage during the first expansion, the drops of water having evaporated before they were able to travel the entire distance. His computations show that the number falling in the first and succeeding expansions should form a decreasing geometrical progression. Nolan and O'Brolchain³ believe that the particles falling in the second and succeeding expansions are due to evaporation from the nuclei while in the pump-barrel and their subsequent ejection into the

¹ Lecture delivered at the Carnegie Institution of Washington, November 13, 1928.

² J. J. Tichanowsky, *Meteor. Zs.*, vol. 45, 107. 1928.

³ P. J. Nolan and Cilian O'Brolchain, *Proc. Roy. Irish Acad. A*, vol. 38, 44. 1929.

receiver, the rate of evaporation in the pump-barrel being hastened by the increase in temperature, brought about by friction between the pump-barrel and piston. They state that the number of particles falling in the receiver should on this basis also decrease according to a geometrical progression. If the first view is correct, in working out the constants of the instrument, the volume of the pump at extreme stroke of the piston must be taken into account; while on the basis of the second view this volume should not be considered but all particles should be counted.

Examination of data, taken from one of the Department's counters made according to specifications given by Aitken,¹ shows that the number of particles falling in the second and subsequent expansions decrease much faster than according to a geometrical progression and are, therefore, not to be completely explained by either theory given above. It is the practice at the Department to admit dusty air into the receiver and make ten determinations for a complete set. The ratios of the number of particles falling on the first expansion to the total falling on subsequent expansions decrease according to a geometrical progression from the first to last determination in a set.

The decrease in number falling from one expansion to the next, although not consistent with Nolan and O'Brolchain's theory, yet may be explained by a modification of this theory. The modified theory requires that the number of particles, from which water is evaporated while in the pump, gradually increase as the counter is used. This is as one would expect, for the temperature of the pump-barrel would tend to become higher, not only because of friction between pump-barrel and piston, but also on account of the hand being in contact with a portion of the piston. While such a theory will explain a decrease in the number falling similar to that observed, it requires that the pump take nearly 70 per cent of all the particles present at expansion. Since the ratio of volume of receiver to that of pump is about three, this requirement can hardly be met. The observed decrease in the number of particles falling on the counting-stage may be accounted for by assuming the presence of particles of several diameters, each falling in accordance with Stokes' law. The relative number of particles in each group could on this basis be computed. Such a theory would not explain, however, the decrease in ratio of particles falling from one determination to another.

Are the Aitken nuclei hygroscopic particles? G. R. Wait.

It is the prevailing notion that the Aitken nuclei are composed only of hygroscopic particles. The results by Wigand² suggest that this notion is correct, as also do the results by Boylan.³ If the nuclei are hygroscopic, then one would expect that the product of the number of nuclei, the limit of visibility, and the relative humidity would be constant. The data on the number of nuclei taken at the Watheroo Observatory in 1924 were subjected to analysis. A number of equations connecting the three elements were tried, in order to find what combinations tended to a result that was most nearly constant. The equation, $V(AR + D) = K$, where V is the limit of visibility (in miles), R is the relative humidity (in per cent), D is the number of Aitken nuclei per c.c., and A and K are constants, fulfilled the requirements best. The interpretation of this equation is that, besides the Aitken nuclei D , there are others, the latter being able to combine with the moisture

¹ Collected papers of John Aitken, 236-246. 1923.

² A. Wigand, *Meteor. Zs.*, vol. 30, 10. 1913.

³ R. K. Boylan, *Proc. Roy. Irish Acad.*, vol. 37, 58-70. 1926.

in the air. The sum of the two acts to limit the visibility to V . Obviously if there are particles that combine with the moisture in the air, but the Aitken nuclei do not, then the latter are not hygroscopic. The data given by Aitken, taken at Kingairloch, although the method of taking the limit of visibility was not accurate, fell in much better with the equation given above than with the one that would permit the interpretation that the nuclei are hygroscopic particles. Lastly, the data over the oceans taken aboard the *Carnegie* also agree with the above equation better than with the idea that the particles there are hygroscopic. From these results one may well ask the question whether, after all, the Aitken nuclei are hygroscopic particles as suggested by the results of Wigand and Boylan.

Relation between the diurnal variation of Aitken nuclei and the diurnal variation in the rate of change of air-temperature. G. R. Wait.

As a result of his investigations on large ions, J. MacLaughlin¹ concludes that the diurnal variation in this element may be accounted for on the basis of a diurnal variation in the rate of change in air-temperature at the place of observation. Nolan, Boylan, and DeSachy² found, over land, a fairly constant relationship between the number of large ions and the number of Aitken nuclei. One would accordingly expect to find a relationship between the diurnal variation of the Aitken nuclei and the diurnal variation in the rate of change in air-temperature. Three sets of diurnal variation of nuclei, made in Washington, together with the diurnal variation in the rate of change in air-temperature from temperature records made simultaneously with the nuclei-count, have been examined. One set of diurnal-variation curves shows a slight similarity in the general features, but the other two show no resemblance either in general features or detailed aspects. The data, although not extensive, fail to show the close relationship that one would expect to exist on the basis of the work cited above.

The effect of large and intermediate ions on ion-counter results. G. R. Wait.

Analysis of data secured on Cruise VI of the *Carnegie* reveals some extreme values for k_+ and k_- , the mobility of the positive and the negative small ions, respectively. The mean values of n_+ (small positive ionic content of the atmosphere), λ_+ (positive conductivity of the atmosphere), and i_+ (the total air-earth current-density) taken for all the corresponding values of k_+ that fall below the value of 0.75 and also for values of k_+ that fall above the value 3.00 are shown in Table 1.

TABLE 1—Comparison of atmospheric-electric results of Cruise VI of *Carnegie*

Group	k_+	n_+	λ_+	i_+	Relative humidity
	$\frac{\text{cm/s}}{v/\text{cm}}$	ions/cc	E.S.U. $\times 10^{-4}$	E.S.U. $\times 10^{-7}$	p. ct.
Values of k_+ below 0.75....	0.52	754	0.67	8.7	83
Values of k_+ above 3.00...	4.03	261	1.41	17.5	81

The presence in the atmosphere of Langevin and intermediate ions has the possibility of increasing the measured value for the small ionic content

¹ J. MacLaughlin, *Annales de l'Institut de Physique du Globe*, vol. 6, 61-85. 1928.

² J. J. Nolan, R. K. Boylan, and G. P. DeSachy, *Proc. Roy. Irish Acad.*, vol. 37, 1-12. 1925.

of the atmosphere over its actual value. This would give values for the mobility that are too small, and thus the small measured values for k , as shown in Table 1, might be explained. This possibility has been examined, keeping in mind the conditions maintained with the conductivity and ionic-content apparatus used during Cruise VI. It is found that the ion-counter acts as a conductivity-apparatus for all ions having mobilities less than 0.08 cm/sec/volt/cm and as an ion-counter for all ions having a mobility greater than this. If the number of Aitken nuclei were the same for Cruise VI as it has been thus far for Cruise VII, then, in order to affect the ion-counter results by as much as 20 per cent, 80 per cent of the Aitken nuclei must be charged and have a mobility of 0.08 cm/sec/volt/cm. In order to affect the ion-counter results by as much as 25 per cent, all the Aitken nuclei must be charged and have the mobility as indicated above. The measurements of Nolan, Boylan and DeSachy¹ over land showed that on the average about 40 per cent of the nuclei were uncharged. If the same percentage of nuclei over the ocean is uncharged, and the charged ones all have a mobility of 0.08 cm/sec/volt/cm, then 15 per cent of the ionic content as measured will be due to these intermediate ions.

Variation of the atmospheric-electric elements over the ocean with certain meteorological elements. G. R. Wait.

An attempt has been made to discover any relationship which may exist between certain atmospheric-electric elements and the relative humidity and the wind-force from data obtained during cruises IV, V, and VI of the *Carnegie*. The relative humidity and the wind-force were each in turn regarded as the independent variable; and potential gradient, the positive and the negative conductivities, and the positive and negative ionic contents were regarded as the dependent variables. Groups of relative humidities were obtained between 55 per cent and 98 per cent, while the wind-force groups were from 0 to 9 on the Beaufort scale.

The ionic content was found to be practically independent of the relative humidity, except at the very highest humidity. The two conductivities decreased rather rapidly and linearly as the relative humidity increased. The value of the negative conductivity was about 1.25×10^{-4} E.S.U. and about 1.15×10^{-4} at 55 and 90 per cent relative humidities, respectively, while the corresponding values of the positive conductivity were 1.45×10^{-4} E.S.U. and 1.26×10^{-4} E.S.U. The potential gradient decreased at the lower humidities investigated and increased at the higher humidities. Regarded as a whole, there was very little change of the gradient with humidity.

The ionic content was rather irregular as the wind-force increased, somewhat higher for a wind-force of 6 than for either higher or lower wind-force. The conductivities were practically constant for wind-forces 0 to 3, then underwent a sudden increase of about 50 per cent, remained high until force 8 was reached, then dropped suddenly. The potential gradient is practically an inverse curve to the conductivities, and almost identical in form to the curve obtained by Sverdrup on the *Maud* Expedition connecting wind-force and potential gradient.

The annual variation in phase-angle and amplitude of the 24-hour wave of the potential gradient. G. R. Wait.

The results from the 59 complete sets of the potential-gradient diurnal-variation runs made over the oceans during cruises IV, V, and VI of the

¹ J. J. Nolan, R. K. Boylan, and G. P. DeSachy, *Proc. Roy. Irish Acad.*, vol. 37, 1-12. 1925.

Carnegie showed¹ that the 24-hour wave of the potential gradient (1) progresses according to universal time, (2) has an annual variation in phase, and (3) has an annual variation in amplitude.

The data from which the above conclusions were drawn were not sufficiently extensive to permit a division into more than four groups. Each group contained data taken during three months. There may accordingly be a reluctance on the part of some investigators about accepting the further conclusions regarding the 24-hour wave by Mauchly that (1) the maximum occurs earlier in the Greenwich day in December than in June, and (2) its amplitude is greater in March than it is in June.

Sufficient potential-gradient data are now available from the recording apparatus on board the *Carnegie* to permit an analysis for each month. There is still some question regarding the proper reduction-factor to be used, especially for different sail-positions, so that it is not possible at this time to say definitely what variation there is in amplitude other than that it seems to be in agreement with the previous data. The data from Cruise VII entirely bear out Mauchly's conclusion regarding the universal feature of the 24-hour wave. Only about two-thirds of a year's results are at hand; thus far, however, the annual variation in phase-angle is progressing in a way altogether similar to that during the previous cruises. The greatest difference in time in the 24-hour wave reaching a maximum during the previous cruises and the present cruise is 0.7 hour.

The specific velocity of the positive and the negative small ions from data obtained during cruises IV, V, and VI of the *Carnegie*. G. R. Waiv.

Modern theories regarding the mobility of small ions in air attribute to each a single mobility when they have reached a final state and when they are under stable circumstances. Since, in the atmosphere, ions are normally being continually formed and the atmosphere is not stable with respect to the amount of moisture and gases it contains, one would expect to find, not a single mobility for each ion, but some variation. The variation one would be able to grant to each ion, however, is not as great as those actually found during cruises IV, V, and VI of the *Carnegie*. It is not only an interesting question but one of considerable importance as to the causes of the variations. If the variations are due to instrumental errors, personal errors, or even to certain peculiar conditions on the oceans, it may be possible to apply corrections that will give us better values for not only the specific velocity of the ions, but for the ionic content and the conductivity. Although considerable work has already been done on this problem, it is not yet possible to give answers to the various questions that have arisen.

It was found that instrumental leaks have not appreciably affected the values of the ionic content and conductivity. The data will need to be weighted, however, according to leg of cruise over which the observations were made. Thus, it will not be correct to take unweighted means for the specific velocity, ionic content, or conductivity in determining their values over the ocean. How much this will affect the published means has not yet been determined. Reexamination of the values used as instrumental constants seems advisable both for the ion-counter and the conductivity-apparatus. The smaller values obtained for the specific velocities seem to accompany small values of the conductivity, and similarly the larger values of the specific velocities accompany smaller values of the ionic content

¹ S. J. Mauchly, *Terr. Mag.*, vol. 28, 61-81. September 1923.

On the effect of temperature, pressure, and relative humidity upon the positive and the negative scale-values for conductivity-apparatus No. 6 used at the Watheroo Observatory. G. R. Wait.

Scale-values for conductivity apparatus No. 6 (positive side 6A and negative side 6B) between the middle of 1924 and the middle of 1927 have been critically examined in order to study the behavior of the apparatus and to deduce the proper scale-values for final reductions.

Empirical equations connecting scale-values with temperature and with a combination of temperature and barometric pressure have been deduced by least-square methods. A study of possible effects of humidity on the scale-value has also been made. From the empirical equations one may calculate with considerable accuracy the scale-value, having given the period for which it is to apply, the deflection or scaling to which it is to apply, and the temperature inside the atmospheric-electric observatory.

It is concluded as a result of this study that effects of pressure and humidity are negligible, but that corrections may be justified for abnormal departures of temperature, especially if the abnormal condition prevails during any calibration-period. If the calibrations are made at approximately the mean temperature for the period over which the particular scale-value is to be applied, the other departures will be largely smoothed out in the grouping of data which are used in most statistical studies. However, in detailed studies any variation of amplitudes less than 10 per cent of the observed conductivity should not be given consideration without taking into account the effect of temperature on scale-value. The diurnal range in temperature within the observatory is sufficiently small that the diurnal variation in conductivity will suffer no effect greater than 2 per cent due to this factor.

The relative frequency of thunderstorms throughout the day over the oceans and in the tropics. G. R. Wait. *Terr. Mag.*, vol. 34, 237-239 (September 1929).

Available data on the frequency of thunderstorms throughout the day over the oceans give a maximum during the night hours. This, Whipple maintains, is because of the greater likelihood of a storm being seen at this time of the day and thinks the data accordingly are unreliable. Humphreys accepts the data and offers an explanation of the phenomenon. Observing the frequency of occurrence of negative potential during the day would seem to be a method of securing evidence on this question that is altogether free from Whipple's objection. Data from the *Carnegie* potential-gradient records thus far sent in have been utilized. The summary shows a double maximum in frequency, one in the forenoon and one in the afternoon, of nearly the same amplitude, with a minimum about noon and another during the night hours. It thus seems to confirm Whipple's contention that the present thunderstorm-data for oceans are unreliable.

There exists a scarcity of data giving the number of thunderstorms, hour by hour in the tropics. There may still be some question as to whether the thunderstorm-frequency on mountains, especially the higher ones, such as the Andes, is the same as it is on lower lands for the various hours of the day. The frequency of occurrence of negative potential during the day as it occurred at Huancayo, Peru, at an altitude of about 11,000 feet above sea-level is compared with the diurnal variation in thunderstorms at two different stations in southern India. The results for the three stations are remarkably similar in every respect. The annual variation in frequency of occurrence of negative potentials at Huancayo is compared with the annual variation in frequency of occurrence of thunderstorms in Peru. The former

gives a maximum in March and the latter a maximum in January. They each show a minimum in July.

Regarding the insulation leak-tests made with the ion-counter and the conductivity-apparatus during the early parts of Cruise VII of the *Carnegie*. G. R. Wait.

Examination of data from the early part of Cruise VII of the *Carnegie* indicated that some factor was effective in producing a variation in the rate of apparent insulation-leak with the ion-counter, the direction of which was in general opposite to the variation in the ionic content. It was concluded that in all probability this was due to air flowing through the ion-counter during the leak-test, the velocity of which increased as the wind-force outside increased. At the same time the ionic content for both the positive and the negative ions decreased with increased air-force outside, thus giving rise to an apparent relationship between the two factors when in reality they are altogether independent.

A similar variation was observed in the rate of the apparent insulation-leak of the conductivity-apparatus with the positive and the negative conductivities. This is possibly due to a failure of the upper cylindrical air-condensers to remove all the ions from the air-stream during the leak-test, the number of ions coming through increasing with increasing air-force outside, coupled with the fact that the conductivities decrease with an increasing air-force outside. These two phenomena likewise are altogether independent, although at first sight the value of one seems to depend upon the other.

The number of Aitken nuclei over the Atlantic and Pacific oceans as determined aboard the *Carnegie* during the early part of Cruise VII. G. R. Wait.

Parkinson has been making determinations of the number of condensation nuclei with an Aitken counter as part of the atmospheric-electric routine

Summary of Aitken counts made aboard the Carnegie, May 21, 1928 to April 2, 1929

Ocean	Leg of cruise		Dates		No. stations	Mean nuclei per cc
	From	To	From	To		
Atlantic	Newport News	Plymouth	1928 May 21	1928 June 8	25	932
	Plymouth	Hamburg	June 18	June 22	...	....
	Hamburg	Reykjavik	Jul. 8	Jul. 19	20	1460
	Reykjavik	Barbados	Jul. 28	Sep. 16	54	672
	Barbados	Balboa	Oct. 2	Oct. 11	21	743
Total and mean for Atlantic Ocean.....					120	870
Pacific	Balboa	Easter Island	Oct. 25	Dec. 5 1929	123	242
	Easter Island	Callao	Dec. 13 1929	Jan. 9	24	151
	Callao	Papeete	Feb. 6	Mar. 12	112	1405
	Papeete	Apia	Mar. 23	Apr. 2	30	1099
Total and mean for Pacific Ocean.....					289	774

on board the *Carnegie* during Cruise VII. There is lack of agreement among observers (see p. 268) regarding the matter of instrumental constants. It is impossible to give values for the number of Aitken nuclei per cubic centimeter over the oceans in view of the uncertainty regarding the exact functioning of the Aitken counter, except with the provision that the values may need to be altered by a constant multiplier, the value of which lies between 1 and 1.6. The results thus qualified are given in the table (p. 274) in which each observation is the mean of ten determinations (for example, in line 1 there was a total of $25 \times 10 = 250$ separate determinations arriving at the mean of 932). It is to be noted that counter D.T.M. No. 4 developed a leak between Easter Island and Callao and that D.T.M. No. 5 was used after leaving Callao.

Apparatus for continuous registration of air-conductivity at sea. G. R. Wait, O. H. Gish, and C. Huff.

Measurements of air-conductivity on the *Carnegie* have heretofore been made by eye-readings on a modified Gerdien apparatus equipped with a Wulf bifilar electrometer. New apparatus designed for continuous registration has recently been completed in the instrument-shop of the Department and tested at Washington. This is to be installed on the *Carnegie* at San Francisco. The method embodied in this apparatus is that described by Swann¹ and now in use at all the observatories of the Department. The distinctive features of this new apparatus are the use of a string-electrometer instead of a quadrant-electrometer, and the compact assembly of most parts of the electrical system in a tightly closed compartment, which is in turn provided with dryer in order that critical points on the insulation of the electrical system may have a maximum of protection. The apparatus is, furthermore, light-tight so that it is unnecessary to have a darkened room in which to operate it. The calibration is performed by means of a variable capacitance instead of by a variable potential-method. The entire recorder is built together as a unit and, while not mounted on gimbals, it is held in place by shock absorbing supports made from sponge rubber. In case the fiber is in considerable motion due to pitch of the vessel, a special design of mercury switch may be used to flash on the recording lamp only when the fiber is in a certain desired portion of its swing.

Investigation of diurnal variation of disturbance at Bowdoin Harbor, Baffin Land. W. F. Wallis.

An investigation of the diurnal variation of disturbance at Bowdoin Harbor for six months' records (December 1, 1921, to May 1922), as measured by the differences between the hourly values for disturbed days and quiet days, shows average maximum disturbance at 12^h to 13^h and minimum at 23^h to 24^h local mean time. This result is strikingly similar to that obtained by Moos from the Colaba results for the period 1894 to 1904, using the differences between the hourly values for all days and quiet days. He found average maximum disturbance at 11^h and minimum at midnight. Chree, however, using hourly character-numbers, found for Cape Evans maximum at 8^h and minimum at 21^h local mean time; and for Cape Denison maximum at 11^h and minimum at 19^h local mean time. From six years' records at Watheroo the average maximum resulted at 18^h to 19^h and minimum at 4^h. Chree investigated the possibility of this variation progressing according to universal time, but was unable to substantiate the hypothesis.

¹ Annual report of the Director, 279-281. 1917.

Comparison of magnetic and earth-current storm records at Watheroo. W. F. Wallis.

A comparison of simultaneous magnetic and earth-current storm records at the Watheroo Magnetic Observatory was undertaken with the object of establishing a cause-and-effect relation between the two. Three well-defined storms (January 29-30, 1924; July 22, 1927; October 22, 1927) were studied in detail, chiefly by means of vector-diagrams, and simultaneous movements of the two phenomena were compared as to direction and amount. There appeared to be no uniformity in the relation between the two except in regard to sudden commencements, when a northwest movement of the earth-current vector usually corresponded to a northeast movement of the magnetic *XY* vector. The short time devoted to this study and the amount of data used are as yet insufficient to permit definite conclusions, but the conclusion indicated is the same as that reached by Bauer in 1922, namely, that there appears to be no direct causal relation between earth-currents and terrestrial magnetism but that both are probably results of some common cause. Bauer reached his conclusion through comparisons of diurnal, annual, and sunspot-cycle variations, and, moreover, his discussion was limited to magnetically and electrically calm days.

TORTUGAS LABORATORY¹

In accordance with authorization by the Trustees of the Institution, investigations were conducted at the Tortugas Laboratory during the summer of 1929. Upon invitation, Dr. Wm. H. Longley, of Goucher College, served as executive officer during the season. Mr. John W. Mills, chief engineer, remained in charge of all equipment. During the past season the Laboratory's vessel, the *Anton Dohrn*, has been equipped with new lifeboats, and tanks have been erected at the Laboratory for the purpose of greatly increasing available supplies of both fresh and salt water. A lead pipe distribution system for sea-water has been installed.

Certain new studies were undertaken and important advances were made in a number of researches continued from previous years.

The following investigators studied at the Laboratory during the season.

- L. R. Blinks. Rockefeller Institute. Resistance and potential measurements across the protoplasm of *Valonia ventricosa*. June 26 to August 5.
- C. M. Breder jr. New York Aquarium and American Museum of Natural History. Development and habits of flying fishes and their allies. May 30 to July 8.
- Martin Burkenroad. Tulane University. Studies upon Plankton and the mechanism of sound-production in Hæmulidæ. May 30 to August 19.
- Paul S. Conger. Carnegie Institution. Diatoms of Tortugas. May 30 to June 10.
- Caswell Grave. Washington University. Stimuli inducing metamorphosis in Ascidian larvæ: Plankton studies. June 26 to August 19.
- Dwight L. Hopkins. Duke University. Locomotion in marine amœbæ. July 24 to August 19.
- W. H. Longley. Goucher College. Habits of fishes and feeding habits of noddy and sooty terns. May 30 to August 19.
- Oliver R. McCoy. Johns Hopkins University. Experimental studies on trematode life histories. May 30 to August 19.
- H. M. Miller jr. Washington University. Behavior of trematode larvæ. May 30 to July 22.
- D. H. Tennent. Bryn Mawr College. Studies on Echinometra. July 10 to August 5.
- William Wartmann. University of Pennsylvania Medical School. Studies on Echinometra. July 10 to August 5.
- Shigeo Yamanouchi. University of Tokyo. Life histories and cytology of marine algæ. June 12 to July 8.

Resistance and Potential Measurements across the Protoplasm of Valonia ventricosa, by L. R. Blinks

The large cells of *Valonia ventricosa* offer logical opportunity for electrical measurements across a single layer of protoplasm. In practice, however, the insertion of a capillary large enough for resistance measurements has caused the prompt disintegration and sporulation of the larger cells. Using smaller cells and the technique of Jacques and Damon, by which a slight pressure is maintained through the capillary, it has proved possible

¹ Situated at Tortugas, Florida.

this summer to maintain the cells of three species alive for some time when thus impaled. *Halicystis* (*ovalis*?) and *Valonia macrophysa* have been used at Bermuda, and *V. ventricosa* chiefly at Tortugas. The results with the latter follow.

The capillaries were less than 1 cm. in length, and 1 mm. or less in outside diameter; when filled with sap they had a resistance of 5,000 to 60,000 ohms. They were connected by salt bridges and agar blocks to amalgamated lead-lead chloride electrodes, essentially non-reactive and non-polarizable as used. A vacuum-tube electrometer was used as detector in the Wheatstone bridge, with a portable Einthoven galvanometer balanced in the plate circuit. The excursions of the galvanometer fiber were photographed when desired on 12 cm. bromide paper in a Cambridge Instrument Company camera.

With one arm of the bridge thrown out, the detector operated as a static electrometer, calibrated for direct readings at sensitivities up to 3 mm. per millivolt. These could be checked by compensating to zero with a potentiometer in series with the cell. No current flowed to the vacuum tube. With the bridge closed for balance a small current could flow through the arms, but the resistances were so high that no diminution of potential was observed after closing the circuit.

Cells freshly impaled and immersed in sea-water gave a small potential (to 5 millivolts) which rapidly fell to zero. After this a slow recovery occurred and after several hours the potential rose to 20 or 25 mv. This is in the direction: *inside positive* to the electrometer.¹

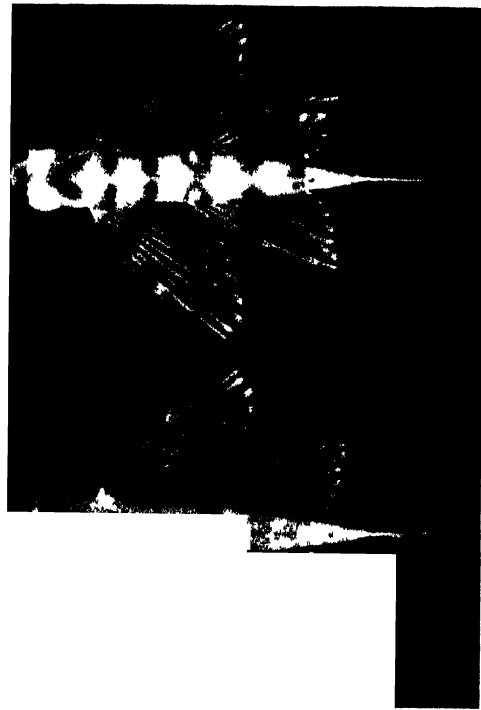
After standing a day or two, the cells often showed a smaller potential which was maintained with fluctuations of several millivolts during the life of the cell. The average potential of some 80 cells measured was about 15 mv., with some as low as 7 or 8 mv. and others as high as 25 mv. In general, the cells which appeared more healthy gave the higher values.

On death, the potential fell to zero. Immersion of healthy cells in artificial sap caused an immediate rise of potential to 40 or 50 mv. (in some cells to 100 mv.) inside positive, followed by a slow decline (in 5 to 10 minutes) to 5 mv., and eventually zero. Restoration of sea-water caused a slow return to normal. Dilute (1/10) sea-water increased the potential to 30 or 40 mv. 0.6M KCl acted much like sap, while 0.6M NaCl reduced the potential nearly to zero.

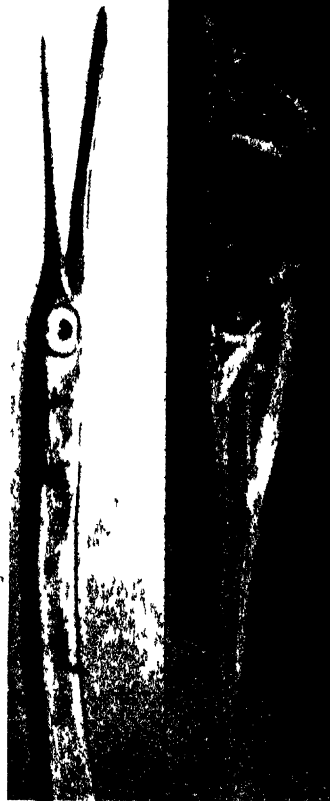
Reversal of sign frequently occurred when, after exposure to NaCl, Mg SO₄ or dilute sea-water, sea-water was restored. The reversal was temporary and amounted to some 30 mv. for a few minutes only. Reversal could also be produced by continued flow of an inward electric current. Conversely, a small outward current tended to increase the natural potential. These are both in the direction of counter EMF's.

The study of transient effects at the closing and opening of circuits gave further information on the phenomena of polarization. In a freshly impaled cell, a current of small size may flow in either direction against no more resistance than would be offered by a dead cell—chiefly the capillary tube. Likewise, an *outward* current may be greatly increased; up to *seven volts*

¹ This is in the same sense as in *V. macrophysa*, though larger. *Halicystis*, on the other hand, shows a potential of 80 to 90 millivolts in the opposite direction: *outside positive*.



1a



6

Fig 1—*Cypselurus furcatus* 69 mm in standard length *a* Dorsal aspect *b* ventral aspect

Fig 2—*Cypselurus furcatus* 8 mm in standard length in swimming attitudes.

Fig 3—Photomicrograph of elongate pelagic egg abundant at the Dry Tortugas in early summer

Fig 4—Sample of discarded fish remains from Bird Key *Paricoratus*, *Monacanthus* and *Cariani*. The high percentage of Exocoetids is typical of all larger samples. Reduced 42.

Fig 5—*Strongylura raphidoma*, *a* Young of 111 mm standard length *b*, Adult of 565 mm standard length

Fig 6—Heads of *Strongylura raphidoma* shown in figure 5



5



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3



4

may be applied without change of resistance. But a moderate *inward* current causes a prompt reactance, and the resistance apparently rises as much as 10,000 ohms in some cells. This is really due to an opposed EMF made evident on breaking the current. This may be as much as 100 millivolts, as shown by the records and by calculation. The records frequently show a symmetrical rise and fall of potential resembling electrode polarization curves. But the cells differed from most electrodes in that polarization was first absent at very small potentials (e.g. below 0.25 volts) and might be greatly delayed (5 to 60 seconds) at about the critical potential (e.g. 0.5 volt). As the cells remained upon the capillaries, however, and recovered from the shock of impaling, the critical voltage became lower and lower, and eventually some cells showed a good reactance with the potentials as low as could be applied, and in either direction. Increase of inward current then produced no rise of apparent resistance but only a greater polarization response, i.e. a rise of counter-EMF, up to the breakdown point, above which the resistance apparently falls. The breakdown point is simply lower for the outwardly directed potential. In both directions the records show the breakdown to be a slower process following a preliminary polarization. It may be related to the maximum potential which the cell can develop in the given direction.

These impaled cells closely resembled intact cells which have partially recovered from the mechanical disturbances of collecting and cleaning. It is believed that these studies clarify the phenomena of resistance levels previously described in these reports for such cells. Likewise, they amplify the observations of Taylor and Whitaker¹ previously made on the natural potential of *V. ventricosa* immediately after the insertion of micro-electrodes.

Report on Synentognath Habits and Development, by C. M. Breder jr.

It is intended that the following data on the order Synentognathi shall form an integral part of a proposed monograph. The accumulated material may best be considered with reference to the three families represented at the Dry Tortugas.

Family Belontiidae

Four species were encountered, *Strongylura ardeola*, *S. notatus*, *S. raphidoma* and *S. acus*. *S. marinus* reported from here by others was not seen, and it is believed that such records refer to *S. ardeola*.² *S. acus* was unknown and *S. notatus* until the present was unrecorded from this place. Color notes were made on the mature forms of each and on the post larval and intermediate stages of three. Although the adults of these fishes have a general resemblance to one another, the young are all highly differentiated and specialized in various divergent ways. That of *S. raphidoma*, at least, is capable of extensive and rapid color change, apparently matching its imme-

¹ Year Book No. 25, p. 248.

² Comparison of this material with other *ardeola* shows that there is apparently a confusion of two forms under one name. Further study is necessary, however, to clear up the exact status of the two forms. One of these is clearly the fish that has been recorded as *marinus*, and neither is of that species.

diate environment in shade and, to some extent, in pattern. The proportional development of the beak proceeds in decidedly different ways in each, suggesting that these species may not be so closely related as one would suppose from a study of the adult fishes alone.

Observations were made on the habit of *Strongylura*, of vaulting over small floating twigs, straws, etc. Both still and motion pictures were obtained. *S. ardeola* seem most addicted to this practice, with *S. raphidoma* and *S. notatus* following in the order named. Sometimes a single fish would leap back and forth as many as a dozen times over a single straw. It is thought that the function of this well-marked habit is that of "scratching" to remove ectoparasites, for it was noted that usually some part of the fish was rubbed against the straw in passing. Second leaps were most often noted when this did not succeed. It is noted in this connection that *S. ardeola*, which was most given to this habit, also most frequently harbored ectoparasites, such as argulids, etc. These fishes, living almost entirely at the surface, do not have recourse to rocks for purposes of scratching, such as do bottom fishes, and it is inferred that they make use of what floating objects they may for such purposes; this apparently "playful" act seeming to have a very practical function.

The post larval Strongylurids at this place are almost entirely confined to the drifting Sargassum. Older, but still young, fish form in schools, usually of a single species and of fishes of remarkably uniform size, and stay close to shore, generally circulating about so that a given school may appear every two or three hours at a given place, in the meantime being replaced by other schools of different species or of different sized individuals. The larger and mature fish spend the daytime ranging about in the more open waters, but come into shore at sunset, apparently for purposes of feeding. At such times the schools of young fishes disband, but they remain close to shore as scattered individuals.

The four species studied mature at approximately the following sizes in these waters: *Strongylura ardeola*, 250 mm. s.l.; *Strongylura notatus*, 300 mm. s.l.; *Strongylura raphidoma*, 800 mm. s.l.; *Strongylura acus*, 650 mm. s.l.

Family Hemirhamphidae

Three species were encountered, *Hemirhamphus brasiliensis*, *Hyporhamphus unifasciatus* and *Euleptorhamphus velox*.

Young stages of the first two were taken in the Sargassum drift, and color notes were made. The adults of the first were seen only in the deeper channels about the islands, and the adults of the second and third were found only on Bird Key as the neglected remains which the Terns had brought to feed their young.

Family Exocoetidae

Three species were encountered, *Parexocetus mesogaster*, *Cypselurus furcatus* and *Halocypselus evolans*.

By far the most attention was given to these fishes. *Parexocetus* is clearly the most abundant and differs from all others known to the present investigator in its manner of development. The young fish, down to a few millimeters in length, at a size at which the wings are as yet too stubby to

permit of flight, so closely resemble their parents as to be recognizable at sight. The simple blue and silver body-color, the lack of pattern on the wings, and the high dark-tipped dorsal are already distinguishing characters at this size. In the adults the reddish tinge of the fins mentioned in the literature as being sometimes present is a distinct secondary sex character. That is, all mature and ripe males show reddish marks on their caudal, ventrals and flanks, while the females remain plain blue and silver. It is suspected that this color appears on the males only with the ripening of the gonads.

In contrast to the development of *Parexocætes*, the young of *Cypselurus* are markedly different from their parents, and show both a great series of pattern and color changes, through which they pass in regular order, and a considerable individual variation. In the field these variegated and elaborately patterned young flying fish show a remarkable degree of resemblance to the floating *Sargassum* and debris in which they are found. This is in marked contrast to the simple blue and silvery young of *Parexocætes* which, while found in the same general localities, are not associated with the *Sargassum* itself, but occupy the clear spaces between its drifts.

Associated with this habitat difference is the possession of mandibular barbels by young *Cypselurus* and the lack of them in *Parexocætes*. In the former they appear to be used in poking about in the weed. This may explain the entire matter of barbels or their absence in fishes of this family.

Considerable effort was expended in a study of the mechanism and modes of flight. While many smaller details were clarified, the question of locomotor wing flapping still remains. It may be mentioned, however, that absolutely nothing was suggested by either experimental or observational methods that would lend any support to the idea that there may be some *functional* wing motion. This holds for the smallest which are just able to clear the water to the largest adults seen.

The field observations of the season have convinced this investigator that Exocætidæ are of much more importance as food in the lives of many animals than one would gather from the literature. In the first place, the young are by far the most common surface fish to be found drifting in the *Sargassum* at this locality. They are approached in numbers only by the various Monacanthids. During the daytime they occur in schools up to thirty or more, but great numbers are scattered as individual fish. At nightfall these schools break up and the young seek more closely the shelter of the clumps of weed. At this time, great schools of *Caranx* and other predaceous fishes are exceedingly active in the pursuit of these small fishes. Flushing one, they follow it along in a pack under water, only to scramble for it as it falls exhausted. If, by chance, it reaches the cover of a clump of *Sargassum* they literally tear it open. It would seem that such a fish once spied has absolutely no chance of escape. *Coryphæna* as small as 30 mm. feeds with avidity on only slightly smaller *Cypselurus*, even in the confines of an aquarium. The Noddy and Sooty Terns of Bird Key apparently feed chiefly on flying fishes. Judging from material collected there from time to time, it is estimated that over three-quarters of their food are Exocætidæ. It is among this material that the single *Halocypselus* was taken—a record new to the Tortugas.

Other data not bearing directly on the Synentognathi may be summarized as follows. Pelagic fish eggs taken in tow nets were sketched and described. Although the identity of several are believed established at this time, they await further study. A key to those encountered is given below for whatever use it may be to other students of fishes at the Tortugas, no attempt being made to name these eggs, all of which reappeared from time to time in sufficient quantity for study. Larvæ were obtained from all, and carried on as far as possible.

KEY TO PELAGIC FISH EGGS TAKEN IN TOW NETS

A. Eggs in a gelatinous cluster, one oil globule present.	
B. Egg diameter 1.1 mm.....	1
BB. Egg diameter 0.65 mm.....	2
AA. Eggs single, not in a cluster, oil globules present or absent.	
C. Egg elliptical, long axis 1.9 mm., over two times short axis, one oil globule.....	3
CC. Egg spherical.	
D. Oil globule present.	
E. Oil globule multiple, diameter of egg 1.2 mm., entire egg pale yellow.....	4
EE. Oil globule single, egg transparent, clear.	
F. Egg less than 1.0 mm. in diameter, 0.7 mm.....	5
FF. Egg over 1.0 mm. in diameter.	
G. Egg greater than 1.5 mm., 1.6 mm.....	6
GG. Egg less than 1.5 mm.	
H. Egg 1.3 mm. diameter.....	7
HH. Egg 1.2 mm. diameter.....	8
DD. No oil globule.	
I. Surface of egg ornamented.	
J. Surface of egg reticulated and covered with short spines, diameter of egg 1.0 mm...	9
JJ. Surface of egg pimpled, diameter of egg 1.6 mm.....	10
II. Surface of egg smooth, without ornamentation.	
K. Diameter of egg less than 1.0 mm., 0.8 mm.....	11
KK. Diameter of egg over 2.0 mm.	
L. Diameter of egg 2.2 mm.....	12
LL. Diameter of egg 3.0 mm.....	13

The egg referred to as "3" is most unusual for a pelagic fish egg, being exceedingly elongate, whereas the usual shape for pelagic eggs, at least, is spherical. This egg was particularly abundant.

Young stages of a variety of species were obtained, including those of *Sphyræna*.

Further data was obtained on the schooling behavior of *Jenkinsia* in reference to larger fishes.¹

A curious reaction was noted in the case principally of *Monocanthus* and *Lactophrys* as a response to a sudden and large increase in the intensity of light. They would gyrate at surprising speed and curious angles, in a manner that would suggest that the entire nervous coordination was upset. Such a reaction on the part of animals so highly organized was not expected.

Report on Sound-production in *Hæmulidæ*, by Martin D. Burkenroad

It has been stated that the "grunting" of *Hæmulidæ* is produced by the air-bladder. It may be proven experimentally, however, that this organ serves only as a resonator. The primary factor in sound-production in these fishes is the grating upon one another of the pharyngeal teeth. Fishes no longer than 30 mm. are able to grunt faintly. Details will be published in an early issue of *Copeia*.

¹ See E. W. Gudger, Carnegie Institution Wash. Pub. No. 391, page 156. 1929.

Diatom Investigations at Tortugas Laboratory 1929, by Paul S. Conger

Diatom investigations at the Tortugas Laboratory in 1929 were conducted during the month of June, as in several previous years, toward the securing of another series of samples from localities of the region differing widely in their oceanographic features, and about 80 such samples from approximately 50 stations were obtained. Several boat trips to new places also afforded unusual opportunities to secure samples from areas not heretofore covered, especially in deeper waters off the Tortugas. Arrangements were made to have plankton collecting continue at regular intervals during the remainder of the summer in order to obtain a good series for the season. Advantage was taken of the night collecting of fishes by other investigators to obtain organisms which might be found to be feeding on the diatoms, and thus numerous small fish, copepods, amphipods and other organisms were taken.

In order to learn something of the rate of diatom deposition in various localities, a set of unglazed tiles was planted, as was done last year; but the methods were improved, and more of the tiles recovered at the end of the season.

Examination of living plankton, the organisms of which are very delicate in the region of the Tortugas, aided very materially in a better knowledge of the diatom species there.

Examination of Pelagic Organisms by Caswell Grave and Martin Burkenroad

Daily towings were made from May 31 to August 19 in the channels and over the reefs in the vicinity of Loggerhead Key by Martin Burkenroad, and examined for pelagic organisms under the direction of Caswell Grave.

The richness of the tow in species and numbers of individuals varied greatly from day to day and with seasonal changes, as is usual in all localities. The record of the forms taken may serve to correct the impression that has become current that the Tortugas region, "once noted for the variety and richness of its floating life," has gradually become "in recent years an almost desert sea."

Specific identifications were possible only for the Medusæ, Siphonophores and Ctenophores. A few hydromedusæ were taken that apparently are not included in Mayor's monograph, and at least one new species was found. The largest number of hydromedusæ taken on one day was seventeen.

The following is a list of the organisms that appeared more or less frequently and often in very great numbers:

Diatoms
Foraminifers
Radiolarians
Sponge larvæ
Planula larvæ
Actinula larvæ
Ephyræ
Hydromedusæ, 29 species
Scyphomedusæ, 4 species
Ctenophores, 3 species
Siphonophores, 5 species
Polyclads

Cercaria larvæ
Pilidium larvæ
Annelid larvæ, trochophores, mitraria, etc.
A Brachiopod larva (Lingula?)
Bryozoan larvæ, including Cyphonautes
Copepods
Ostracods
Isopods
Nauplius larvæ
Zoeas

Megalops larvæ	Ophioplutei, 4 species
Squilla larvæ	Echinoplutei, 2 species
Chaetognaths	Spatangoid plutei, 2 species
Lamellibranch veligers	Tornaria larvæ
Gasteropod veligers	Ascidian tadpoles
Pteropods	Appendicularia, 4 species
Young squids	Chain and solitary salpa, several species
Bipinnaria larvæ	Pelagic fish eggs
Large yolk-laden larvæ of star fish	Leptocephalus
and holothurians	
Auricularia larvæ	

The organisms taken which occasioned general interest, on account of their unusual characters, were the *Auricularia nudibranchiata* (of Chun), several stellate aggregations of cercariæ, their tails adherent, and a *Turritopsis medusa* containing several parasitic *Cunioctantha*.

Evidence of periodicity in the spawning activities of several species was afforded by the contents of the tow on several occasions when the water everywhere was filled with eggs.

The Palolo worm "swarmed" seven days in succession, June 28 to July 4 inclusive, about the last quarter of the moon which occurred on June 30. Two other large swarms took place apparently without relation to moon phases on July 17 and 18.

The eggs of seven other species were also abundant on the morning of June 29. The large pink eggs of a gorgonian were extruded in very great abundance during the early mornings of June 29 and 30 and of July 26, 27 and 28. The air, by a strong odor of gorgonian tissue, on these occasions gave evidence that the gorgonians had spawned.

Continuation of Study of the Influence of Light on the Behavior and Metamorphosis of the Larvæ of Ascidians, by Caswell Grave

The experimental study of metamorphosis of the larva of *Polyandrocarpa tinctoria* was continued by Caswell Grave from June 26 to August 19.

After many broods of larvæ had been treated and examined, it became apparent that the effectiveness of stimulation by changes in light intensity depends upon an internal factor that varies in larvæ of the same brood, and markedly so in different broods of the same colony. It may be fully differentiated in a brood of larvæ at the time of its liberation, or may be partially differentiated or wholly absent.

In broods in which this factor is fully differentiated, immediate subjection to a series of 30 one-minute exposures to darkness, each followed by a one-minute exposure either to diffuse sunlight or to a beam of light from a 32C Mazda electric light bulb at a distance of 23.5 cm., is effective in inducing attachment and metamorphosis of the larvæ at the bottom or side of the containing vial. In one brood, which showed the greatest susceptibility observed, 100 per cent metamorphosed after treatment involving but 15 such exposures.

In many broods metamorphosis was not induced by the standard treatment (30 changes in light intensity), or by twice or even three times the standard "dose," but it was finally found that if, in such resistant broods, an interval of one, two or three hours is allowed to elapse after the first treatment, during which interval the vial containing the larvæ stands

in light of unchanging intensity, a second standard treatment is successful in inducing an epidemic of metamorphosis.

Steps in the formulation of a working hypothesis involving the development or differentiation in late larval life of a factor upon which the initiation of metamorphosis depends, need not be enumerated here; but record should be made of facts that may be involved in the final solution of the problem of the mechanism of metamorphosis of the larva of this ascidian.

Polyandrocarpa tinctoria in its normal habitat is attached to the under side of coral rock and is found on shallow sandy bottoms. It thrives in a live car in which water rises to a depth of a few inches. Colonies that are daily transferred from the live car to large bowls in the laboratory are not thereby injured but continue to grow and produce larvæ.

A mature colony has been observed to liberate a brood of larvæ on each of two consecutive days, but none has liberated broods three days in succession. This fact has a bearing on the possible age of larvæ at liberation.

The number of larvæ in a brood varies with the size of the colony, from about 30 to 250, but in a large colony consecutive broods tend to be fairly constant in number.

When liberation of larvæ by a colony begins, the process is continuous and the time that elapses from the emergence of the first larva to that of the last of the brood varies from about 10 to 25 minutes.

The hour of day when the liberation of a brood may be expected is not predictable. Broods have been liberated as early as 8^h 30^m a.m. and as late in the afternoon as 3 o'clock, but they usually appear between 10^h 30^m a.m. and 12^h 30^m p.m.

Susceptibility of larvæ to the effect of stimulation by changes in light intensity is not correlated with the hour of liberation. One brood liberated at 8^h 35^m a.m. showed immediate susceptibility, while another liberated at 1^h 53^m p.m. showed none.

The several broods liberated in the laboratory during the summer have shown no observable differences in the form, size or activities of their constituent larvæ, although they have shown great differences in susceptibility to the effects of stimulation by abrupt changes in light intensity.

An histological study of the structural organization of larvæ of different susceptibilities to stimulation may reveal differences due to advancing development and differentiation, indicating the location of the structure or substance upon which the "releasing" stimulus acts in initiating the process involved in attachment and metamorphosis.

A dissection of mature colonies preserved for the purpose may reveal facts concerning the time and sequence of germ-cell formation, fertilization and embryonic development, indicating the age of larvæ constituting a brood.

A limited number of experiments was made to determine whether mechanical stimulation may not be equally as effective as changes in light intensity.

Seven broods of larvæ were each divided into four lots, one of which was not treated but served as a "control." The other three were treated simultaneously, one to a series of 30 one-minute exposures to darkness each followed by a one-minute exposure to diffuse sunlight; one to a similar treatment with light from a 32C mazda bulb; while the third was treated to

30 one-minute intervals of continuous stimulation by the impact of the clapper of an electric door bell upon a shelf on which the vial containing the larvæ rested, each interval of this mechanical stimulation being followed by a one-minute interval of quiet. The larvæ in this vial were exposed to light of constant intensity.

The results of mechanical stimulation are unsatisfactory as a basis for final interpretation, but they seem to show that mechanical jars, when properly applied to susceptible larvæ, are effective as a releasing stimulus to the process of metamorphosis.

In four of the experiments, no effect in accelerating metamorphosis by mechanical stimulation was shown; in two experiments a slight acceleration of the process of metamorphosis occurred, but markedly less than in vials subjected to stimulation by light intensity changes, while in one a greater acceleration was induced by mechanical stimulation than by changes in light intensity.

Light intensity changes were effective in inducing a significant percentage of metamorphosis in all of these, while in the "controls" the cases of metamorphosis that occurred took place much later than in treated vials.

The fact that changes in light intensity and mechanical stimulation have both been shown to be effective in accelerating metamorphosis suggests that the series of changes involved in attachment and metamorphosis of the larva may be released by any form of stimulus that can be properly applied.

The further question presents itself—does the advent of metamorphosis depend upon larval activity and does it follow only after the larva has, by its activity, used up some reserve of stored energy? This question can not now be satisfactorily answered, but observations of larvæ under many conditions have given the impression that activity in itself is not sufficient to account for the results obtained.

It is a fact, however, that during treatment with light intensity changes, every larva is thrown into immediate and vigorous swimming activity the instant the intensity is reduced and that a similar but less intense activity follows each increase in light intensity, except that in the latter case a latent period varying from 2 to 10 seconds elapses before the larvæ begin to swim.

Comparison of the Relation of Osmotic Pressure, Hydrogen-Ion Concentration, and the Concentration of Calcium to Locomotion of Marine and Fresh-water Amœbæ, by D. L. Hopkins

In the past few years I have studied the chemical and physical factors involved in locomotion of fresh-water amœbæ. Fresh-water has in it, but in more dilute solution, practically all the chemicals found in sea-water. Therefore, I was anxious to ascertain to what extent the adaptation on the part of marine amœbæ to a much higher concentration of salts affected their reactions to these substances.

It has been found that the fresh-water amœba, *Amœba proteus*, will not move about in distilled water, but if ions such as will dissolve from ordinary glass into distilled water in a few hours' time are added, locomotion is made possible. It will not move in Clark and Lubbs's buffer, made up by adding KOH to KH_2PO_4 until a pH of 6.6 is obtained and then diluted

20 times. However, if CaCl_2 is added to this diluted buffer again, locomotion is made possible. As the concentration of CaCl_2 is increased, the rate of locomotion increases until a maximum rate is obtained at a concentration of about 0.0008N. Then as the concentration increases the rate remains more or less constant for a considerable increase of concentration, but finally as the concentration is still further increased the rate drops off until it reaches zero at about 0.1N CaCl_2 . The maximum rate is first obtained when the CaCl_2 concentration is about equal to the calcium concentration of normal fresh water. Reduction of the osmotic pressure of the medium of *Amæba proteus* by dilution of spring water has no noticeable effect on the rate of locomotion until a deficiency of salts, such as is found in redistilled water, is obtained. Then locomotion ceases. Increasing the osmotic pressure by adding a non-electrolyte such as lactose or dextrose causes a cessation of locomotion when a concentration of 0.1M has been added.

MATERIAL AND METHODS

The marine amœbæ used for this comparison were collected in tidal pools at Tortugas. Great numbers of them were cultured in finger bowls by adding two grains of wheat to about 100 c.c. sea-water, and inoculating with the collection. In five days an abundance of amœbæ was present in the cultures. The amœbæ selected for the experiments were of the "limax type" and corresponded very closely with Schaeffer's *Trichamœba pallida*. However, no uroids were noticed and the size of the different individuals varied more than did those described by Schaeffer as *Trichamœba pallida*, the length varying between 20μ and 60μ . For the experiments, animals were selected varying between 35μ and 55μ in length with an average of 45μ , and a width varying between 10μ and 15μ with an average of 12.5μ . The technique used in making up solutions and obtaining the rate was the same as used in my previous work on *Amæba proteus*.

RESULTS

No locomotion was obtained in distilled water, Clark and Lubb's buffer pH 6.6 diluted 20 times, or in the buffer to which has been added enough NaCl or KCl to make the medium isotonic with sea-water. Neither was any locomotion secured by adding CaCl_2 to the buffer in a concentration of 0.02N, making a medium in which *Amæba proteus* moves about readily. But if this combination of buffer and CaCl_2 was made isotonic with sea-water by adding NaCl or KCl a high rate of locomotion was obtained. If dextrose were added to this buffer- CaCl_2 medium until it was isotonic with sea-water locomotion was also made possible, but the rate was not nearly so high as when NaCl or KCl was added. It would appear then that the difference between marine and fresh-water amœbæ in their reactions is not merely one of adaptation to different osmotic pressures but also an adaptation to difference in concentration of monovalent salt.

The relation between the concentration of the salts in sea-water and locomotion was ascertained by concentration and dilution. The highest rate was obtained in normal sea-water, the rate dropping off gradually to zero as sea-water was diluted or concentrated. By making 0.5 sea-water isotonic with normal sea-water by adding dextrose, an improvement in rate over that

obtained in 0.5 sea-water was obtained but did not give a rate nearly equivalent to that in normal sea-water. The addition of dextrose to normal sea-water caused a cessation of locomotion when the medium was made isotonic with 2× sea-water, while by concentration of the salts in sea-water a fairly high rate was obtained at 2× sea-water. These facts seem to show that the salts do not act in a purely osmotic fashion.

By the addition of CaCl_2 to Clark and Lubb's buffer pH 6.6 which had been diluted 20 times and then made isotonic with sea-water by addition of KCl, the highest rate was obtained around 0.02N CaCl_2 , which is approximately equivalent to the amount of Ca in normal sea-water.

In order to study the effect of the hydrogen-ion concentration, HCl was added to sea-water to make it more acid, and NaOH was added to make it more basic. The highest rate was obtained in the neighborhood of pH 8.0. This rate gradually dropped off as the medium was made more acid or more basic. At pH 5.0 locomotion was zero and at a pH between 10 and 11 it also became zero.

In conclusion it should be observed that with reference to salts, calcium, hydrogen-ions and to osmotic pressure, the highest rate of locomotion of these marine amœbæ is obtained at concentrations approximating that found in the natural medium, sea-water. The same seems also to be true for fresh-water amœbæ.

Observations on Tortugas Fishes, especially those on which the Noddy and Sooty Terns of the Bird Key Rookery Feed, by W. H. Longley

Information difficult to summarize continues to accumulate regarding Tortugas fishes. Representative observations only may be cited.

(1) *Ogilbia cayorum* is viviparous. As many as five young may be born together.

(2) Examination of the contents of the intestine and of the pellets of indigestible material voided by a number of minnows (*Hepsetia stipes*) newly caught in one school shows that these masses tend to be very uniform in composition, though the material for several unlike one another may be present at once in one fish. Some contain the remains of several hundred copepods. Others have no copepods, but the carapaces of a dozen or more ostracods or Cumacea. Some too have the remains of the various sorts commingled, but one is able to see clearly that these plankton feeders do not find their food everywhere uniformly dispersed, but encounter here a drifting swarm of one and there another organism.

(3) New light has been obtained upon the relation of the fishes known as *Thalassoma nitidum* and *Thalassoma bifasciatum*.

Of the former, 28 specimens examined were males, 83 females. Of the latter, all of 19 were males. Since Beebe and Tee Van collected a suite of 16 specimens of *bifasciatum* in Haiti, of which all were males, the evidence is now strongly in favor of the idea that there are no females of this sort. But between the *nitidum* and the *bifasciatum* type every degree of difference occurs. Moreover sperm of either sort of male fertilizes the eggs of *T. nitidum* with equal facility. There, therefore, seems no escape from the conclusion that the two forms belong to one species in which the females and

young males are alike in appearance, but the males of the second season or later of a very different one. Since the *bifasciatum* type was first named the species must go by that title.

Regarding the very unequal sex ratio it may be noted that of 39 specimens of *nitidum* collected in shallow water 38 were females. With them were 7 *bifasciatum*. From deep water, *nitidum* females were 45, males 27; *bifasciatum* males, 12. Counting the two sorts of males as of one species, a sex ratio not far from equality is indicated, since the shallow-water population is, I believe, much the smaller part of the whole.

Turning now to the food of the tern colony, the material studied consists of fishes and squids, more or less digested, and dropped and lost by parents feeding their young. Some thousands of specimens were collected and classified. Differences in the vertebræ separate most of the genera at a glance, and other osteological differences very commonly suffice to distinguish the species when external form and coloration fail.

The collections diminish in quantity as the young birds grow older, but in composition change little as the season passes. Chief in importance always are the flying fishes *Parexocætes mesogaster* and *Cypselurus furcatus*, up to about 8 inches in length. Other Synentognathi include *Strongylura*, *Athlennes*, *Hemirhamphus*, and, more commonly than these, the flying halfbeak *Euleptorhamphus velox*.

Carangids are very common. These include many *Caranx ruber* and *crysos*, and a few *Caranx latus* and *bartholomæ*. There are many dolphins (*Coryphæna hippurus*) up to 6 inches in length, many *Selar crumenophthalmus*, not so many *Psenes cyanophrys*, fewer *Seriola dumerili* and a few *Decapterus punctatus*. Besides these, of Scombroid fishes *Gymnosarda* is rather common, and *Gempylus serpens* by no means among the rarest.

Monacanthus hispidus up to $2\frac{3}{4}$ inches is very common. It comes from the floating gulf weed. *Monacanthus ciliatus* and *Alutera* are fairly common. Other genera identified include, roughly in order of their abundance, *Priacanthus*, *Sardinella*, *Jenkinsia*, *Holocentrus*, *Amia*, *Cephalacanthus*, *Lonchopisthus*, *Bathystoma*, *Upeneus*, *Pomacentrus*, *Lagocephalus*, *Diplectrum*, *Bollmania*, *Kyphosus*, *Spheroïdes* and *Halichæres*.

This is a list in which, from the point of view of the collector, novelties abound. Ten species are new to Tortugas. *Euleptorhamphus velox*, *Lonchopisthus micrognathus*, and *Bollmannia boqueronensis* are little known anywhere. The rare Cephalopod *Spirula* falls a prey to the birds from time to time with them.

It is puzzling how *Priacanthus* up to 3.0 inches is taken by the dozen, and young *Holocentrus*, and adult *Amia* (all of which one would suppose nocturnal), and even more how *Bollmania* and *Lonchopisthus* (which should be bottom fishes of deep water) are caught as often as they are. One thing only is clear: The pelagic fishes of the several hundred square miles of deep water over which the birds feed outside the Tortugas atoll provide the greater part of their food—the shallow waters in shore, relatively little.

Besides involving a slight contribution to knowledge of animal distribution, the observations upon the food of the terns permit one to see a little more clearly in what intricate relation to one another and to other organisms the fishes stand.

Dolphins, for example, are among the greatest scourges of flying fishes. But with the flying fishes the young dolphins up to 6 inches in length suffer too in large numbers. In this fact one sees something of the balanced forces in the flying fishes' environment. For them, in a sense, the attacks of the terns are no added burden. The birds take only what the dolphins they kill would otherwise destroy.

Study of the food masses containing several fishes still adhering to one another—usually of one species and almost always with heads pointing in the same direction—and their own food still identifiable in the stomachs of a few, permit one to learn much of the associations in which the different species occur and something of their movements before their end came.

Further Life History Studies on Marine Trematodes, by O. R. McCoy

The investigation of the life histories of the trematodes at Tortugas, Florida, was continued primarily by following up intensively the leads which were suggested by last summer's work. In addition a number of new cercariæ, metacercariæ, and adults were found which open possibilities for the solving of more life histories.

A cotylocercous cercaria from the snail, *Astræa americana* (Cercaria B of Miller, Year Book No. 24, 235) was proved experimentally to be the larva of *Hamacreadium gulella*, a parasite of the gray snapper, *Lutianus griseus*. This life cycle exactly parallels that of *Hamacreadium mutabile* which was reported last year (Year Book No. 27, 280-284). The cercaria of *H. gulella* is distinguished from the cercaria of *H. mutabile* by the possession of 14 stylet glands instead of 8. Both cercariæ penetrate and encyst in the tissues of small fish as second intermediate hosts. In experimentally infested gray snappers, *H. gulella* became sexually mature about 15 to 20 days after feeding. The time required for *H. mutabile* to become sexually mature was somewhat longer—19 to 24 days.

Experimentally the cercariæ of both *H. mutabile* and *H. gulella* encysted in ten species of small fish selected at random. But the slippery dick, *Halichæres bivittatus*, was the only species in which cysts were found to occur naturally. Cotylocercous cercariæ habitually attach to the substratum with their sucker-like tails. Since the slippery dick burrows into the sand at night, there would be an excellent chance for the cercariæ to penetrate these fish to encyst.

A number of experiments were undertaken with *H. mutabile* and *H. gulella* to throw light on some of the relations of these parasites to their hosts. The complete data which include nearly 100 gray snappers will not be given, but the results are briefly summarized under the following heads:

Cross-Infection—The development of *H. mutabile* was tested in 6 species of fish representing 5 different families. The worms developed only in two species, *Lutianus griseus* and *Ocyurus chrysurus*, both of the family Lutianidæ. The development of *H. gulella* was tested in 8 species representing 6 families, but again the worms developed only in species of the family Lutianidæ. There is some evidence, however, that a larger proportion of the worms will develop in the gray snapper than in the other species of the family.

Infectivity of Cysts of Different Ages—Cysts of both *H. mutabile* and *H. gulella* were not infective on the first or second day after the cercariæ

had penetrated the fish. About half of them were infective on the third day and all on the fourth. The infectivity did not increase or diminish for cysts up to 12 days of age.

Rate of Loss of Worms—Approximately equal doses of cysts of *H. gulella* were given to a series of gray snappers by feeding them equal numbers of small fish from a lot infected with the cercariæ under identical conditions. Table 1 shows the rate of loss of worms in a series of 8 fish killed at different intervals after feeding. These data are confirmed by the results from two other series of fish. No explanation is offered for this rapid and practically complete loss of worms in heavily infected fish. In a single series of fish which were given only a light dose of cysts, about 10 to 15, the worms were not lost but were recovered as long as 30 days after feeding.

TABLE 1—Rate of loss of worms in a series of gray snappers given equal doses of cysts of *Hamacreadium gulella* and killed at different intervals after feeding

Snapper No.	Number of small fish fed	Age of cysts	Killed-days after feeding	Worms recovered	Average number for each interval
23.....	5	6 days	3 days	320	....
24.....	5	6 days	3 days	473	397
27.....	5	6 days	6 days	311	....
28.....	5	6 days	6 days	25	168
44.....	5	6 days	15 days	6	....
45.....	5	6 days	15 days	22	14
78.....	5	6 days	24 days	0	....
79.....	5	6 days	24 days	4	2

Superimposed Infections—Two series of experiments were carried out in which one half of a lot of gray snappers were given a heavy dose of worms. After 15 days these fish were fed a second heavy dose and the control half of the lot was given an equal dose. All of the fish were killed after 6 days and it was found that a large number of worms from the second feeding had started to develop in the previously infested fish. The number developing in the previously infested fish, however, was only about two-thirds of the number developing in the control fish.

A new cotylocercous cercaria was found in *Columbella mercatoria* which is intermediate between the two cotylocercous larvæ, Cercaria I and J which Miller (Year Book No. 24, 237) reported from this host. The new species will be designated Cercaria V and a brief description of its morphology is appended to this report. None of these three species of cercariæ encysted in small fish. Cercaria I, however, on one occasion encysted in a small shrimp.

Mature metacercariæ of *Cercaria floridensis* (Cercaria P of Miller) were obtained again this summer in small fish which had been infected with the cercariæ four weeks previously. Infected fish were fed to a Noddy Tern, a Sooty Tern, and a Booby; the birds all died within a week, however, and no developing worms were recovered.

The tow collected and examined daily by Mr. Martin Burkenroad yielded a total of 5 new species of cercariæ. One of these was identical with a form which occurred frequently free in the mesoglea of medusæ, particularly *Æquorea forskalea*, as many as several hundred specimens being found in a

single medusa. The anterior end of this metacercaria was heavily pigmented, a complete digestive tract was present, and an unbranched excretory vesicle filled with large concretions extended to the region of the pharynx. This metacercaria appears to be the larva of *Lepocreadium trulla*, a parasite of the yellow-tail. The similarity of very young developmental stages found in the fish makes the identification highly probable, but there is no experimental proof of the life cycle.

During the course of the season, 8 new species of metacercariæ were found encysted in medusæ, ctenophores, crustacea and small fish but the adult relationships of these forms were not determined. It may be of interest to report the following as yet unidentified adult flukes new to Tortugas: a blood fluke occurring interlaced in the intestinal mucosa of the yellow-tail; and two monostomes from a young Noddy Tern which must have acquired its parasites at Tortugas.

CERCARIA V

Small cotylocercous cercaria from *Columbella mercatoria* with tail about half as long as body when contracted but capable of extension to twice the length of body. Definite sucker present on end of tail. Ventral sucker slightly larger than oral sucker. Double-pointed stylet present; 4 pairs of stylet glands with 4 bundles of ducts, the most lateral of which are difficult to distinguish. Walls of excretory vesicle composed of large, conspicuous cells. Sporocysts small, anterior end protrusible; irregular patches of bright orange pigment scattered over surface.

Continuation of Study on Behavior and Reactions of Marine Cercariæ from Tortugas, by Harry M. Miller jr.

Work of previous years (Year Books Nos. 24-26) on the behavior of larval trematodes under experimental conditions has been continued and extended. Attention was confined to the cercariæ which infest *Cerithium litteratum*, *Astræa americana* and *Columbella mercatoria*, as no new mollusk host has been found since 1925; and as in previous years, including 1928 (McCoy, Year Book No. 27), the first-named host proved to be the best source of experimental material. During the present season three new and generally similar species of cercariæ (temporarily designated Cercaria T, U and W) were found in *C. litteratum* during a joint survey by O. R. McCoy and the writer, thus bringing the total number of species infesting this common reef snail to ten.

The finding of these three larvæ, all huge-tailed monostomes, together with Cercaria F, which continues to be the most common cercaria at Tortugas, and with the writer's previous study of *C. purpuracauda* from Puget Sound, makes it now possible to generalize concerning certain aspects of the behavior of the members of this morphological group. All are monostome cercariæ possessing pigmented eyespots and very large, more or less highly pigmented tails. The mature, active larva of each species is strongly photo-positive, and swims more or less incessantly, in general as previously described for Cercaria F. While neither the actively swimming nor the "fatigued" individual of a typical species of this group responds to a change in light intensity, Cercaria T after having come to rest on the substratum may be activated by decreased illumination (shadow).

An interesting feature of the behavior of *Cercaria W* is its aggregation into masses composed of as many as 35 individuals, and the photopositive movement of the cluster as a unit. Two aggregates were taken this year by Mr. Burkenroad in the surface tow off Loggerhead Key. Later when *Cercaria W* was found for the first time infesting *C. litteratum*, and subsequently on a number of occasions, sufficient mature cercariæ were available in several cases to enable the writer to observe the formation of the aggregates in a watch-glass. This is effected by means of the posterior half of the tail, which tapers suddenly to a narrow ribbon of even width and has adhesive properties. The photopositive movements of the cercariæ brought them together in the most highly illuminated region of the watch-glass, and the sticky posterior halves of the tails became tangled in the center by chance movements of the cercariæ; the rest of the cercaria projected out along any radius of the spheroidal mass of wriggling worms. No semblance of such aggregations was found in freshly teased gonads, and it is not probable that so large a mass could pass out through the ducts. As the snail host lives in the shallow water on the top of the reef where the tide is in almost continual movement, it is unlikely that these large aggregates are formed in the open water. It seems more probable that the aggregation takes place in the branchial chamber of the snail, after the cercariæ have emerged individually. The only other records of the natural occurrence of such clusters of larval trematodes, known to the writer, are those of *C. clausii* from the Mediterranean Sea and *C. gorgonocephala* found by Ward in Lake Erie.

The cotylicercous, or "stumpy-tailed," cercaria is a type whose behavior has not previously been studied in detail. The behavior and reactions of two species, the cercariæ of *Hamacreadium mutabile* and of *H. gulella*, were studied during the past season, and some observations were made on two other species. This type of cercaria does not swim actively, as it possesses only a very short tail. It is able to move along a substratum in either of two ways, by inchworm locomotion effected by the use of the oral sucker and the sucker on the end of the stumpy tail, or by creeping in a similar fashion by the aid of the oral and ventral suckers. When progressing by means of inchworm locomotion the behavior very much resembles that of a leech. The cercaria of *H. mutabile* was particularly studied in this respect. The body of the cercaria, attached to the substratum by means of the tail sucker, greatly extended itself, curved slightly on the ventral surface; the anterior sucker attached, the tail sucker immediately released, and the body bent quickly and the tail sucker was placed just behind the oral sucker. Then the oral sucker released its hold, and the body swung backward through an arc of almost 180°, ventral surface up and dorsal surface occasionally touching the substratum. The cercaria then assumed a perpendicular position, and if the series of movements was not repeated it remained upright and swayed about.

In some infestations the cercaria of *H. gulella* was markedly photopositive; the cercaria of *H. mutabile* did not react so strongly to light. The cercariæ of both species were stimulated to increased activity by a shadow falling upon them; cercariæ which were upright reacted almost immediately by very rapid bending and turning in all directions, and even almost mature

individuals lying on the bottom of the container twitched and bent their bodies when so stimulated. Mature cercariæ were not visibly affected by being struck with a needle, but when the aquarium was sharply jarred a response occurred similar in character to that which followed a shadow.

The distinguishing characters of the three new monostome cercariæ, similar to *C. equitator* Sinitsin, *C. purpuracauda*, and Cercaria F, are given below. The temporary designation by letters is continued. All three infest *Cerithium litteratum*.

CERCARIA T

Huge-tailed, binoculate monostome with scattered melanoid pigment in body in region of eyespots, and yellow, orange and melanoid pigment in localized regions of translucent tail. Body similar to that of Cercaria F; exact number of penetration glands not determined, but at least 5 pairs of ducts distinguished, in 1 median and 2 lateral bundles. Readily distinguished from all others of group by shallow, rectangular "suction cup" (?), with raised edges on dorsal side of proximal part of tail; usually seen in lateral view. Pair of dorso-lateral, knob-like protuberances at proximal end of suction cup, prominent under cover-glass pressure. Distal two-thirds of tail widely annulated. Mature, free-swimming cercaria strongly photopositive; activated by reduced illumination when resting on bottom of aquarium. Development in large, orange-pigmented rediæ; pharynx easily visible, short gut and birthpore present.

CERCARIA U

Huge-tailed monostome, with dark eyespots characteristic of group and with highly pigmented (yellow-orange) tail. Body proportionately much larger than in all other members of group; in Cercaria F tail length bears a proportion to body length of approximately 20 to 1; in Cercaria T, 9 to 1; in Cercaria U, 5 to 1. Cercaria U easily distinguished from others by this proportion of parts and by its highly pigmented tail. Mature cercaria swims incessantly for long periods, strongly photopositively; method of locomotion like that of other members of group. Development in plump, colorless rediæ; birthpore, pharynx present, but no gut observed.

CERCARIA W

Binoculate monostome cercaria with huge tail distinctively pigmented and highly modified from typical form in the group. Body generally similar to that of others; 2 sets of penetration gland ducts on each side, lateral and dorso-lateral, as usual in these cercariæ. Short, proximal region of tail finely pigmented, yellow-brown in color; small pigment masses scattered between cells of remainder of tail. Sharp taper at middle of tail; distal half a narrow ribbon of uniform diameter with adhesive properties. Mature cercaria strongly photopositive; aggregates formed by adhesion of ribbon-like portions of tails also photopositive. Formation of these clusters, with ends of tails tangled in center of mass, observed in watch-glass containing teased gonad of *Cerithium*; found also in surface tow.

An Experimental Study of the Behavior of Cercaria floridensis in Relation to its Fish Intermediate Host, by H. M. Miller jr. and O. R. McCoy

The behavior of *Cercaria floridensis* has been studied (Cercaria P; Miller, Year Books Nos. 25, 26), and McCoy (Year Book No. 27) found it to develop to the metacercarial stage in small fishes. In the present study we attempted to determine whether and to what extent the behavior of this cercaria is adaptive. The experiments fall under three headings: penetration reactions in the presence of various animal secretions and fluids, longevity and infectivity of the cercaria, and infestation of fish intermediate hosts under different conditions of light.

C. floridensis is a small lophocercous larva with pigmented eyespots, which swims intermittently. It is photopositive, and is immediately activated to swim upward by decreased illumination (shadow). If the shadow is of very short duration, the path of the latter part of the swim is abruptly changed so that the cercaria progresses toward the light side of the container. By means of a series of brief shadowings, the most reactive cercariæ were segregated and pipetted off to form a "suspension," equal portions of which were added to the containers used in each experiment.

Small pieces of feather were smeared with mucus from intermediate hosts, the yellow grunt (*Hæmulon sciurus*) and slippery dick (*Halichæres bivittatus*), with mucus from a medusa (*Cassiopea*), a conch (*Strombus*), and from human saliva. These were held on the bottom of watch-glasses containing sea-water and active cercariæ. In a short time some of the cercariæ had come to rest on the mucus surfaces, and some had become entangled in the mucus; others underwent typical boring movements and sooner or later dropped their tails. The greatest boring activity occurred in fish mucus and saliva mucus, and the least, practically none, in conch mucus, although numerous cercariæ were entangled in it. No boring movements occurred on untreated feathers. When mucus from the above sources and fluid from the compressed muscles of three species of fish were each mixed with agar-agar solution and poured into small dishes to solidify, there was no significant difference in the behavior of cercariæ added in sea-water over the jelly in experimental and in plain agar-agar control dishes. Apparently there is no "chemical" attraction of the cercariæ to the tissues of the intermediate host. In the experimental dishes the larvæ reacted only after they had become caught in the mucus.

Longevity and Infectivity of Cercariæ—More than 350 small grunts, a non-specific intermediate host, were used in these and in the following experiments. The cercariæ penetrate and encyst under the scales and in the fins, but do not invade the tissues. Degree of infestation was measured by counting the cysts in the seven fins; since the combined surface of these represents more than one-third of the total body surface this may be considered a fair sample. After infestation, the fishes were kept for 12 hours until the cercariæ had encysted; the cysts were then easily counted. No correlation was found between the size of the fish and the number of cysts within the size range of the fishes used—about 4 to 6 cm. Three experiments were carried out, using selected cercariæ. The results of the third and most extensive experiment are briefly described. Approximately 3,200

cercariæ were added to one liter of sea-water in each of 11 glass aquaria, which were covered with glass plates and placed in a water table in which the temperature did not vary more than 2° C. At the end of 2 hours, and at 3-hour intervals thereafter, 8 small grunts were placed in one of the aquaria and exposed for one hour to the cercariæ. As the experiment extended for a period of 36 hours, all exposures were made in a darkroom to eliminate the factor of shadows which activate this cercaria. After a suitable time the cysts in the fins of each fish were counted (Table 1). The average number was fairly constant until the fifteenth hour, after which there was a rapid decline. The last exposure was made 6 hours after the tenth one, and an average of only one cyst per fish resulted. Since numerous individuals were alive at the end of the experiment, although mostly decauded and crawling on the bottom of the aquarium, it would seem that the infectivity of *C. floridensis* continues as long as the cercaria has means of reaching its host.

TABLE 1—Number of cysts found in fish exposed to cercariæ of different ages

Age of cercariæ in hours.....	2-3	5-6	8-9	11-12	14-15	17-18	20-21	23-24	26-27	29-30	35-36
Number of cysts per fish (aver).	37.7	44.6	39.0	49.5	30.5	16.9	9.1	10.9	6.1	3.1	1.0

Infestation of Fish under Different Conditions of Light—Because of the fact that this cercaria is so sensitive to shadows, experiments were planned to determine whether the infestation of fish in the light would be greater than that of fish kept in total darkness. Six aquaria, each containing approximately 1,800 cercariæ and 3 fish in 5 liters of water, were placed in strong diffuse daylight, and 6 in a dark room; the exposure time was 3.5 hours. The fish in the light contained an average of 49.1 ± 1.6 cysts and those in the dark, 64.6 ± 3.1 cysts; the difference is statistically significant. In the second experiment the fish were confined to the upper or lower third of the water by means of coarse wire screens. Sixteen aquaria, each containing 5 fish and approximately 1,700 cercariæ, were used, 4 under each condition of the experiment; the exposure time was 3 hours. In the case of the fish which were "confined down" there was a significantly higher average number of cysts in those fish which had been in the dark; among the "confined up" fish those which had been in the light had a significantly higher average number of cysts.

As the latter, rather than the first part of the second experiment, is a more critical test as to whether shadows play a rôle in the infestation of the grunt with *C. floridensis*, it was repeated on a slightly larger scale. Ten aquaria, each with approximately 3,000 cercariæ and 5 fish, were used; all fish were "confined up," 5 aquaria in the light and 5 in the dark, exposure time of 3 hours.—The fish in the light again had more cysts than those in the dark room, the results being more significant statistically than in the original experiment.

It is probable that these significant differences are due mainly to the wider distribution of the cercariæ in the aquaria in the light; possibly also the reaction to shadow is a factor. Undoubtedly the reaction to shadow is instrumental in bringing more cercariæ to the upper levels of water in the aquaria kept in the light. The possible rôle which shadows play in infestation will be discussed fully in the detailed publication of the experiments.

Figures are the average number counted in the 8 fish exposed at each time interval (Page 296).

Continuation of Studies in Echinometra at Tortugas, by D. H. Tennent

Work was carried on at Tortugas from July 10 to August 5. During this time a supply of *Echinometra* material, fixed by the Champy-Kull and the Ludford-Mann-Kopsch processes was prepared. The study of this material was completed at Woods Hole during August and September.

At Tortugas a study of the influence of solutions of NaCl, CaCl₂, and SrCl₂, isotonic with sea-water, on the electrical charge carried by *Echinometra* eggs, was made. In this work I had the assistance of Mr. William Wartmann, whose services were made available to me by the Director of the Cancer Research Fund of the University of Pennsylvania.

Cytology and Life Histories of Marine Algæ, by Shigeo Yamanouchi

During four weeks at Tortugas, Dr. Yamanouchi availed himself of the opportunity to become acquainted with the marine flora of the region. He collected material for later cytological study, and completed preparations for experimental investigation of selected life histories during the Laboratory's next season.

ARCHÆOLOGY

Morley, Sylvanus G., Santa Fe, New Mexico. Associate in American Archæology. (For previous reports see Year Book Nos. 13-27.)

The two principal investigations in Middle American Archæological Research—the Chichen Itzá Project and the Uaxactun Project—completed their sixth and fourth seasons, respectively, during the current year. As in former years, subsidiary expeditions were sent out to other sites, one to the Old Empire city of Piedras Negras in the northwestern corner of the Department of Peten, Guatemala, the other to the New Empire center at Macanxoc-Cobá in northeastern Yucatan, Mexico.

The staff for 1929 consisted of the following members: At Chichen Itzá—Sylvanus G. Morley, Associate in charge; J. O. Kilmartin, engineer and administrative assistant; Karl Ruppert, archæologist in charge of excavations; H. E. D. Pollock, assistant archæologist; Miss Katheryn MacKay, housekeeper and trained nurse; Miss Bess L. Holbrook, secretary and book-keeper; A. J. Kerr, mechanic; at Uaxactun—O. G. Ricketson jr., in charge; A. L. Smith, assistant archæologist, Mrs. O. G. Ricketson jr. and E. Shufeldt, field assistants; and in Washington—E. H. Morris, archæologist; Mrs. E. H. Morris and Jean Charlot, artists, who were engaged in preparation of the final report upon the excavation of the Temple of the Warriors. In the group at Chichen Itzá there should be included the personnel of the Yucatan Medical Expedition of the Department of Tropical Medicine, School of Public Health, Harvard University: G. C. Shattuck, director; J. C. Bequaert, entomologist; J. Sandground, helminthologist; K. Goodner, bacteriologist; and B. L. Bennett, laboratory technician.

Dr. Morley reached Mexico City on January 1, and after conferences with Lic. Ezequiel Padilla, the new Minister of Public Education, and Mr. Jose Reygadas y Vertiz, the Director of Archæology, proceeded to Yucatan. The other members of the staff reached Yucatan on December 31, by way of New Orleans, and work was resumed at the Caracol, or Astronomical Observatory, on January 23.

Pursuant to the policy of commencing no new unit of excavation until work already under way should be completed and published, excavations at Chichen Itzá during the current season were restricted to the Caracol (Station 5), study of which was begun in 1925, continued in 1926 and 1927, but suspended in 1928, and supplementary studies at the Casa Redonda (Station 15).

The most important discovery at the Caracol during the current season was the finding of an earlier circular substructure, buried within the upper rectangular platform, from which the tower proper rises. This circular substructure is in perfect condition, still retaining its original plaster finish, but as yet no stairway has been found connected with it, by which access could have been gained to the tower on the summit. This discovery has made necessary further excavation, in order to determine the constructional details involved, as well as extensive repairs to preserve and at the same time expose the buried substructure, so that another season's work will be

required to complete the study and repair of this architectural unit. For a detailed description of the work at the Caracol during the present year, see Mr. Ruppert's report on page 303.

Another major activity at Chichen Itzá during 1929 was a continuation of the survey of the site by J. O. Kilmartin, Assistant Topographical Engineer, U. S. Geological Survey. In 1923, Mr. Kilmartin surveyed the central area comprising the larger and better-known architectural units, using a scale of 1:200,000 and 5' contour intervals. This year an even larger tract (nearly a mile square) lying immediately south and southwest of the central area was surveyed, and all constructions noted thereupon. The same scale and contour interval were employed in each case, and it is proposed to republish the two maps as one. Several important and previously unreported architectural groups were located by this survey and a number of stone causeways were found connecting them, the most important being the one running from the Monjas in the middle city to the Group of the Hieroglyphic Lintels at the south end, almost a mile in length. For a description of this survey see Mr. Kilmartin's report on page 312.

A third major activity at Chichen Itzá during the present year was the medical survey of the surrounding region by the Yucatan Medical Expedition of the Department of Tropical Medicine, School of Public Health, Harvard University, under Dr. G. C. Shattuck, undertaken as a cooperative project with the Carnegie Institution. Three different groups of Maya and mixed-bloods were examined (1) the laborers at Chichen Itzá, largely drawn from the neighboring villages of Pisté and Kaúa; (2) the inhabitants of Dzitas, the nearest railway point to Chichen Itzá; and (3) the inhabitants of Chankom, an Indian village lying 14 miles southeast of Chichen Itzá. Surveyed maps of the last two villages were made by Mr. Kilmartin, giving location of houses, wells, latrines, corrals, pigsties, etc. Vital statistics, sanitary conditions and prevalent diseases were tabulated for all three groups, and blood and fecal specimens secured from several hundred individuals. The most surprising feature of the survey seems to be the almost complete absence among the Maya either of syphilis or the probably related yaws so prevalent in other tropical countries. For Dr. Shattuck's report of the medical survey see page 301.

A fourth activity at Chichen Itzá during the current season was the free clinic conducted by Miss MacKay. The clinic is now in its third year and has been steadily growing; 624 cases were treated at Chichen Itzá, Pisté, Xocenpich, Dzitas, Kaúa, Yulá, Nictchá and Chankom this year, in some cases patients walking as far as 30 miles for treatment. Medicines are distributed gratis, and this feature of the Project, so ably conducted by Miss MacKay, has had an important part in creating the very friendly relations existing between the Indians of the surrounding region and the members of the Institution's staff at Chichen Itzá. Miss MacKay's report on the Chichen Itzá Clinic will be found on page 315.

Excavations were closed at Chichen Itzá on June 15, and the members of the staff returned to the United States shortly thereafter—Dr. Morley and Messrs. Kilmartin, Ruppert, and Pollock by way of Mexico City; Miss Holbrook and Mr. Kerr by way of New Orleans. Miss MacKay returned to her home in Mexico City.

Through the courtesy of Dr. E. L. Hewett, Director of the School of American Research and the Museum of New Mexico, Dr. Morley has occupied offices in the Palace of the Governors, at Santa Fe, New Mexico, for the past three years. Summer quarters were opened here on July 1, and Dr. Morley, Messrs. Kilmartin and Ruppert, and Miss Holbrook spent parts of the summer and fall there. Mr. Kerr returned to Chichen Itzá to take care of the hacienda early in August.

Report of Dr. G. C. Shattuck on the Yucatan Medical Expedition

At the suggestion of Carnegie Institution of Washington the "Yucatan Medical Expedition" was organized by the Department of Tropical Medicine of the School of Public Health of Harvard University. It was financed jointly by the Institution and by the Department. The Expedition, making its headquarters at Chichen Itzá, worked under the auspices of the Carnegie Institution. The members of the Expedition were Dr. G. C. Shattuck, director, Dr. Joseph C. Bequaert, entomologist, and Dr. Jack H. Sandground, helminthologist, from the Department of Tropical Medicine; and Dr. Kenneth Goodner, bacteriologist from the Department of Bacteriology. Mr. Byron L. Bennett served as laboratory technician. Members of the Expedition, except Dr. Bequaert, whose departure was postponed, sailed from New York on February 1, 1929.

Work was begun at Chichen Itzá on the day of arrival, February 8, although it was some days later before the portable laboratory was completely set up and fully equipped.

The object of the Expedition was to make a preliminary medical survey of Yucatan. With this purpose in view two centers of population, Dzitas and Chankom, were selected for special study. Dzitas exemplified the small town of mixed population having railway communications with the outer world, and Chankom typified the large, isolated village of practically pure Maya stock. In both places free clinics were held which made it possible, not only to examine a large proportion of the entire population of these localities, but also to supply the laboratory with quantities of material.

The physical examinations made in the clinics showed the development of the individual, his state of nutrition and the presence or absence of characteristic physical signs of diseases. The laboratory studies included estimates of hemoglobin, typing of blood specimens, Kahn and cholesterol reactions which have a significance like that of the Wasserman test, examinations of blood smears for malaria, Schick testing to determine susceptibility to diphtheria, examination of fæces for protozoön or helminthic parasites, such as the amœba of dysentery and the hookworm, culturing the fæces for pathogenic bacteria, and bacteriological testing of water supplies.

Local epidemiological data were obtained by abstracting the records of births and deaths in Dzitas, and by house-to-house visiting and census taking in Dzitas and in Chankom.

Meanwhile, numbers of patients were examined and treated almost every day in the laboratory at Chichen Itzá and visits were made to various Indian villages. Conditions in them were found to be similar to those in Chankom.

After Doctors Sandground and Goodner had completed their work and returned home, the laboratory was virtually closed. I then made a visit to Uxmal, where malaria has been prevalent in the past. Subsequently, I undertook two trips into the forests of the Territory of Quintana Roo to compare conditions there with those in Yucatan and to learn what I could about the prevalence and distribution of an interesting ulcerative disease known locally as "chiclero ulcer" or "piquete de mosca." I had previously seen a few examples of this disease in Yucatan but they had been contracted in Quintana Roo.

The first journey was from Tizimin to the "Colonia Santa Maria," about 80 to 90 miles distant by road and trail, and the second was to Xyatil and Xpichil which lie about 95 miles southeast of Peto. My party on these trips included Mr. Bennett and Sr. Felipe Castillo of Dzitas who served as interpreter.

Clinics held at the "Colonia" for five days gave opportunity to examine a considerable number of Mexicans. Through the good offices of Srs. Cué Hermanos our party was provided with mules for the journey in both directions and was housed and fed at the "Colonia" without charge.

The trip from Peto was very kindly arranged for me by Sr. de la Torre of the Mexican Exploitation Company and by Mr. Joseph F. Rehani of Merida. The object was to visit the Indians at Xyatil and Xpichil who live under conditions differing from those at Chankom and who are even more isolated.

Dr. Bequaert, who was to collect biting insects and plants, postponed his coming until after the rains had begun because of the scarcity of insects and of flowers in the dry season. He reached Merida on May 29 and proceeded the next day to Chichen Itzá. Subsequently, he spent a week at Chankom and, later, he obtained important information from Dr. Gaumer at Izamal. I sailed for home on June 24 and Dr. Bequaert followed on July 8.

The work of the Expedition has provided much information about the prevalence and distribution of disease in Yucatan. This information relates not only to bacteriological and parasitic diseases but to maladies of nutrition as well. There is also a large quantity of statistical data upon infectious diseases in the districts of Merida, Progreso, Ticul, Valladolid and Peto, which was laboriously copied from unpublished official sources, and a quantity of meteorological data, based upon official observations over a period of five years at Merida. Dr. Sandground's work in helminthology extended beyond man to the lower animals, from which a number of most valuable specimens were obtained.

Collections of bacteriological, helminthological, pathological, entomological and botanical material were brought back by the Expedition to be worked up in the home laboratories. Samples of water and of soil were also secured. Doctors Bequaert and Sandground each obtained a few zoological specimens.

It will require a good deal of time to study all this material and to prepare a report upon the work of the expedition as a whole.

Mr. J. O. Kilmartin of the Chichen Itzá Project kindly prepared maps of Dzitas and of Chankom to be used in the Report.

The Expedition not only carried out its program, but extended its activities over a somewhat wider field than was originally contemplated. This success is attributable to various favorable factors and especially to the enthusiastic work of my associates, the friendly spirit of both Yucatecans and Indians, and, lastly, but not least, to the helpful cooperation of Dr. Morley and his Staff at the Hacienda in Chichen Itzá.

*Report of Karl Ruppert on the Excavation and Repair of the Caracol
(Station 5)*

Excavations at the Caracol group during the current season may be considered under three heads: I, The Caracol; II, The West Annex; III, The South Annex.

I—THE CARACOL

Excavation of the north, east and south faces of the upper terrace was commenced on January 23, in order to permit the repair of these walls and to examine the sculptured and faced stones which had fallen not only from the upper terrace, but also from the Caracol proper above the five-member cornice.

The following sculptures were recovered from the east side—two contiguous cornice elements presenting glyphs, which had been parts of a serpent with hieroglyphs carved on the body; other parts of this same serpent-cornice without glyphic treatment; elements from the mask panel above the east doorway; a seated human figure in full round; and various decorative elements which may have formed parts of the panel of which the seated figure was the central element. The sculptured material found on the north side was about the same as that on the east side.

Fifty-seven stone incense burners have been recovered from the Caracol. Some of these may have been used in connection with the tower itself as two were found relatively high in the debris on the upper terrace; but it is believed that the greater number were placed on the parapet of the upper terrace, as indicated by finding ten of them spaced at regular intervals in the debris across the base of the terrace wall on the south side.

To ascertain the nature of the foundation supporting the great weight of the central core of the tower, a pit was dug in the inner corridor directly inside the south doorway. The foundation was found to be composed of large rough stones, well embedded in mortar to a depth of 13 feet 8 inches; below this level the fill contained comparatively small amounts of mortar.

At a depth of 5 feet 2 inches below the floor of the corridor several horizontal tunnels were noted, averaging 4 inches in width and 8 inches in height. They are very definitely indicated, although made of rough stone.

Thirteen feet one inch below the floor and directly beneath the center of the core of the Caracol proper was a stone-lined and roughly circular cist, 12.5 inches in diameter and 19 inches in height. The cist was covered with stones and the floor was of untroweled lime-mortar.

In the center of the floor of the cist a vertical shaft, 2.5 inches in diameter, extends to a depth of 27.5 inches. The upper 7 inches of this is roughly lined with mortar showing vertical striations which would tend to indicate

that the shaft had been formed by laying wet mortar around a pole, and withdrawing it after the mortar had partially set. Four horizontal tunnels leading away from the sides of the cist have the following bearings: N. 24° 30' E., N. 65° 30' W., S. 37° 5.18' E., S. 65° 30' W. They average 5 inches in width and 8 inches in height.

An *olla* had been placed in the hollow directly over the small opening in the floor. It is 9 inches in height, of dull red-brown ware with heavy brushed decoration. It was half filled with earth in which were mixed pieces of a sandstone disk similar to those found by E. H. Morris at the Temple of the Warriors¹ and elsewhere. This disk had a diameter of 5 inches. There were also found seven pieces of hematite mosaic, a small stone button, one surface of which was painted red, and a squared shell ornament.

In the process of clearing the debris on the east side of the upper terrace, a circular substructure, the original upper terrace, was discovered. This rested directly on the lower terrace, and rose to a height of 11 feet, terminating with a 15-inch vertical cornice. The diameter of the newly discovered circular platform is approximately 53 feet, i.e. 17 feet greater than the Caracol tower.

Surrounding the circular platform, except for a section of about 40 feet on the western periphery, is a bench 4 feet 3 inches wide and 3 feet high, finished with an 8-inch vertical cornice. As yet no stairway has been found leading to the summit of this circular platform. The openings or mouths of small horizontal tunnels were noted at various levels in the facing and at the base of the bench. In some cases these tunnels were blocked by the later fill material which had been built around the circular platform, and in other cases they had been prolonged by crudely built passages in the fill. These tunnels are not always straight, as for example, one on the west side makes two turns before it opens through the faced wall of the upper platform. Since the upper platform has not yet been completely excavated, the relationship between these openings and the tunnels encountered in the shaft sunk in the inner corridor of the building is as yet unknown.

A cache of skeletal material was encountered in front of the west doorway at the edge of the cornice of the original circular substructure. The material extended from 7 to 25 inches below the surface but not more than 2 feet west of the cornice. The first indication of this cache was the discovery of a nest of cranial fragments belonging to at least 13 different individuals; altogether, scattered throughout the fill, were found, complete or in part, sections of 18 different lower jaws. Even though this material was in very poor condition the area occupied by each skull was clearly indicated in the fill. They were placed in very closely packed rows, three being found under the cornice. No attempt at orientation had been made and long bones were scattered indiscriminately throughout the area.

From the position of the material and the fact that stones were wedged in between bones as if purposely, there can be little question that these are secondary burials. Funeral furniture includes sherds of a rather plain incense burner and the lower jaw and two vertebræ of a deer.

¹ Year Book No. 27, page 297.

As excavations were continued around the cornice toward the northwest, an *olla*, 14 inches in diameter and 15 inches in height, was uncovered 4 inches below the surface. It was half filled with ash under which were two excellent obsidian flakes, 4 and 4.5 inches in length, respectively.

A trench in the floor of the niche between the double stairway leading to the summit of the second terrace exposed a masonry platform measuring 84.5 inches in length, 70.5 inches in width, and 12 inches in height. Resting on this platform were two round columns. The top of the platform is 4 inches below the base of the sides of the steps and extends under them a distance of 17.5 inches on the south side and 11 inches on the north side. The back wall of the niche rests on top of this platform. The northern half of the platform, as well as the column resting on it, was painted black, while the southern half and the southern column were painted red.

Scattered throughout the dirt fill of the area between the stairways, to a depth of 16 inches, were found fragments of human bone. There were two foci of concentration of this material—one along the southern side of the niche, 33 inches west of the platform, and the other 45 inches west and on the east and west axis of the niche. The latter represents secondary or disturbed burials as sections of skulls and teeth were found scattered throughout the fill. Skeletal material recovered includes the following teeth and miscellaneous bones: 43 molars and premolars, 33 incisors, 24 canines, 1 lower jaw, 1 right and 1 left tibia, 1 humerus, 1 clavicle, 2 ulnas, 1 atlas, besides fragments of ribs, long bones and skulls. Burial objects include 90 jadeite beads, 2 pieces of obsidian and a few miscellaneous shards and portions of shell.

During the season of 1927 two drains were found in the floor of the lower terrace.¹ This season a third was found on the east side, 107.5 feet north of the southeast corner of the terrace. Only a section of its south and west faces remains *in situ* due to the fall of the cornice above at this point.

Excavations along the parapet of the lower terrace, south of the main stairway, established that it had been 44 inches in width and at least 33 inches in height. Four openings, somewhat regularly spaced, which pierce this section of the parapet at the level of the floor of the terrace, may have served as drains. They vary in height from 6 to 10 inches and in width from 8 to 12 inches. A small stairway built against this parapet will be described in connection with the West Annex.

The stairway leading to the top of the lower terrace was subjected to a number of alterations. In its final stage it consists of two sections. The four lower steps have 3 foot 3 inch treads and 10.5-inch risers. The three lower steps have a gradient of 78° with the horizontal, and the fourth, one of 65°. This flight of four steps is 71 feet long and gives on to a platform 21 feet wide, which projects 8.5 feet beyond the upper section of the stairway at both ends. However, with the subsequent construction of the West Annex, the southern foot and a half were covered by the platform of the Annex. The western face of this platform rises with a batter equal to that of the riser of the final step, while the north and south faces are vertical.

¹ Year Book No. 26, page 249.

The second section of the stairway begins to rise at a point 13.75 inches behind the front line of the platform. This portion of the stairway is 43 feet 10 inches wide and its medial axis coincides approximately with the medial axis of the lower flight of steps. The risers average 9.87 inches high, and the treads, 13.75 inches wide. At either side were balustrades, 18 inches in width, each carved with a pair of intertwining serpents. The two heads and two tails belonging to the tops of the balustrades were recovered. The two tail stones were of highly specialized shape being carved so as to fit vertically, directly below the protruding heads, the tip of each tail extending beyond the outside edge of the balustrade.

An earlier period in the construction of the upper section of the stairway is shown by the painted lime-plaster floor of the platform, which extends under the balustrades to the facing walls of the stairway and also under the steps on the west side for a distance of 7 feet 9 inches. This indicates that at one time the stairway was without balustrades and rose at a greater angle.

The lower section of the stairway, as well as the platform, rested on a well polished lime-plaster floor, painted red. A pit sunk into the platform at the south, and a tunnel driven in for a distance of 12 feet under the stairway at the north, showed this same red floor continuing under the platform and stairway and curving up against the west face of the lower terrace and against the roughly plastered section of masonry protruding from the terrace, and extending under the stairway. The significance of this section of masonry and the floor curving up against it can not be determined until after further excavation.

Abutting the first riser of the lower section of the stairway at a point 14.5 feet south of its northern edge is a still lower step, which gives directly on to a paved stone roadway, 13 feet wide. This extends in a northwesterly direction some 120 feet to the south wing of a building called No. 6 on the Maudslay map of Chichen Itzá and described by him as "a tumbled heap of stones now about 4 feet high, which may at one time have supported a roofed building."

Finally the south balustrade of this stairway, composed of a pair of intertwining serpents, has been restored to its original position so far as possible, although a few of the sculptured blocks are still missing.

When Mr. Reygadas, Director of Archæology for the Ministry of Public Education, visited the Caracol on March 9, he expressed the wish that the five-member cornice of the Caracol, as well as the arch of the outer corridor, might be entirely replaced except for the section on the east, where it had fallen *en bloc* without disintegrating, to within a few feet of the upper terrace floor. With this in view, work was started on the repair of the outer east wall, and continued until the five-member cornice was entirely replaced except for this single section.

The exterior wall of the Caracol has been raised to a height of 46 inches above the five-member cornice, which involved replacement of the masks over the north and east doorways. The arch of the outer corridor has been repaired to an equal height on the inside. The fallen walls of the second terrace have been replaced and the parapet raised to the highest surely established level.

II—THE WEST ANNEX

The West Annex consists of a low platform built against the west side of the lower terrace of the Caracol, to the south of the stairway, surmounted by a small temple. The platform measures 51.75 feet on the north, 46.5 feet on the south and 64.5 feet on the west. The battered facing rises with a gradient of from 76° to 80°, to a height of 7.66 feet where it terminates with an angular cornice, overhanging 3 inches.

Two stairways give access to this platform. The principal one, on the west side, 24.66 feet from the northwest corner has a width, including the balustrades, of 15.33 feet. Each balustrade was 18 inches wide and carved in low relief to represent a serpent. The serpent heads, which had stood at the tops of the balustrades, were not found.

The other stairway is on the north side of the platform and measures 7 feet 10 inches in width, including the two 15-inch balustrades. The outer facing of the western balustrade rises vertically from a point at the top of the battered face of the platform reached by the lower section of the Caracol stairway.

In the debris to the west of the platform and south of the main stairway were found six large, finely dressed stones, the original positions of which have not yet been determined. These stones are 28 inches in height, battered on one face and vertical on the other. These two faces, as well as the top, have been worked and plastered. A seventh stone similar to these was found on top of the platform, 4 feet south and 2 feet west of the north anta of the temple proper. The finding of this one stone above the platform suggests that they pertain to the temple rather than to the platform. Placed side by side vertically as was undoubtedly their original position, they have a combined length of 7 feet 11 inches.

The temple measures 28 feet east and west by 46.5 feet north and south. It is so placed on the platform that a narrow passageway only 22 inches wide has been left between its back wall and the battered western face of the lower terrace of the Caracol.

A cross-section of the west wall of this temple reveals a vertical zone rising from the platform to a height of 7.5 feet. Upon this rests a three-member cornice, having battered lower and upper members, 9 inches high each, separated by a 6-inch vertical member. No portion of the wall above the first member of this cornice was found *in situ*; however, the height of the fallen upper part of the façade may be calculated, with reasonable accuracy from data recovered in the course of excavation. It seems likely that above the three-member cornice there was a vertical zone 3 feet 6 inches high, upon which rested another three-member cornice similar to the first, with the exception that the top member is 18 inches in height. This gives a total height for this temple of 15.75 feet.

The upper vertical zone, with the exception of the east side which was plain, was decorated by a continuous band of simple U-shaped motifs 8 inches in height, incised on the wall stones, and large decorative niches in the middle of each side. In each niche a seated human figure forms the principal motif. The figures in the north and south niches are seated cross-legged. Although these are not as finely executed as those found by E. H.

Morris in 1926 in front of the Northwest Colonnade,¹ they are in the same style. The figure from the north niche has a bird beak and a tubular nose plug.

The temple has two chambers; the outer one is a colonnaded hall having two rows of four columns each, which support the corbelled arch roof. It is 41 feet 6 inches long by 14 feet wide, the long axis running north and south. The antæ have an average length of 3 feet 5 inches. The round columns average 19 inches in diameter and with their rectangular capitals, have a total height of 6.5 feet. Three stones bearing the incised U-shaped motif were found *in situ* in the facing of the east wall.

Entrance to the inner chamber was gained through a doorway 4 feet wide, the jambs of which were standing to their original height of 6.5 feet. The inner chamber is 40 feet 9 inches long by 7 feet wide.

Directly in front of the doorway there is an altar 13 feet long, 4 feet 10 inches wide, and 2 feet 2.5 inches high including the 6-inch vertical cornice, which overhangs 3 inches. Faint traces of geometric designs in red, green, tan and black were noted on the cornice, while on the sides large yellow flowers were naturalistically portrayed. The top of the altar was painted a dull red, similar to that used as a background for the painting on the sides.

Three niches in the front or western face of the altar open at the floor level. They average 18 inches in width, 20.5 inches in height and 27.5 inches in depth; the under side of the cornice forming the tops. Each niche is formed of carefully laid wall stones which still retain traces of their original coat of bluish-gray plaster. Standing upright in each niche approximately 12 inches from the face of the opening is a dressed stone about 12 inches high. These stones are roughly rectangular and rounded at the top, and are almost identical in shape with a stone found in the inner corridor of the Caracol in 1927.²

A cist 6 inches in diameter and 12 inches deep was found in the floor, 13.5 inches west of the altar and in line with the middle niche; a flat stone 9.5 by 11 inches, buried half an inch beneath the well-polished lime-plaster floor, served as a cover.

Shortly after excavations were started in the inner chamber a highly unusual arrangement of dressed stones was uncovered. These formed a wall or step, one tier in height, 22 inches in width and 64 inches in length. At each end of this wall, or steplike construction, there was a single rectangular block having a width equal to the wall and extending above it. To the west of this construction, at its base and abutting it, was a rectangular arrangement of vertical cornice stones having a total width of 29 inches, and a length equal to that of the wall or step itself. This construction was found some 52 inches above the altar, to which position it had settled when the arch of the inner chamber had fallen.

Subsequent excavation along the parapet surrounding the lower terrace of the Caracol revealed a small stairway directly east of this fallen steplike construction. As this small stairway has a width equal to that of this fallen construction just west of it, it seems probable that at one time both together

¹ Year Book No. 25, page 285.

² Year Book No. 26, page 251.

formed a flight of steps which led from the top of the lower terrace of the Caracol upward to the roof of the West Annex. The roof of the latter must have been approximately 5 feet above the top of this lower terrace.

Encased within the hearting of the platform of the West Annex was found an earlier platform which is intact except for its southwest corner. The present south face of the platform seems to be merely a western extension of the south face of this earlier platform, which measures 32 feet 5 inches by 32 feet 3 inches and is finished with a 9-inch vertical cornice.

Shortly before the close of the season the stairway of this earlier platform was discovered against the middle of the western side; it is 9 feet 3 inches in width, including the plain balustrades. Due to lack of time only the three upper steps were uncovered.

Repair of the West Annex has been completed. A section of the wall of the south platform has been left unfaced to allow for the removal of dirt, when excavation of the buried stairway is undertaken.

III—THE SOUTH ANNEX

The South Annex is the group of low-lying structures at the south base of the lower platform of the Caracol. This group was only partially excavated during the current season, sufficient, however, to disclose a complicated series of colonnaded halls and chambers. As yet the western limit of the group has not been established. The north wall of the section excavated was built against the batter of the lower platform of the Caracol. The eastern wall is 44 inches west of the southeast corner of the same platform. The east face of the South Annex rises with a batter to a height of 38 inches on which rests an 8-inch battered cornice. This wall extends south a distance of 35 feet 7 inches, where it abuts the western base of an arched gateway, which is 13 feet 9 inches long and 7 feet 2 inches wide. The arch and wall stones had been painted red. The gateway and adjoining areas to the north and south are paved with flagstones.

West of the gateway there is a covered colonnade, supported by two rows of round columns, which extends across the south side of the partially excavated Annex. At a distance of 29 feet 8 inches west of the eastern limits of the colonnade, a doorway 5 feet 3 inches in width opens into a chamber measuring 38 feet 4 inches by 21 feet 10 inches. The corbel arched roof was supported by four round columns. Against the north wall there is an altar approximately 6.5 feet square and 2 feet 10 inches high.

There are four doorways giving out of this chamber, two in the east and two in the west wall. Those in the east wall give into two other chambers. The southern one of these is 12 feet by 20 feet 7 inches, and built against its east wall is an altar similar in size to that found in the large outer chamber. The north chamber is 21 feet 3 inches by 20 feet 1 inch.

Returning to the two doorways in the west wall of the outer chamber, the southern one had been closed up in ancient times with masonry fill and the northern one gives on to an as yet unexcavated area.

Occasional sculptured stones were found built into the walls. The provenience of only one seems surely established. This is incised with the U-shaped motif, found on blocks from the façade of the West Annex.

Part of a door jamb with warriors sculptured on its three visible faces was also found on the surface, before excavations were begun. Two of these figures have the head of an animal as their head-dress, and carry shields made of wooden slats, in one case the grip for the hand being clearly represented.

SUMMARY

The chronological sequence of these several structures, so far as revealed, seems to indicate that the large lower platform of the Caracol formed the first unit. Extending in front of its western base was the red lime-plaster floor upon which rested the platform reached by the lower section of the lower stairway. The various changes in the construction of this stairway must await further excavation before final elucidation.

Built directly on this red-painted floor, and to the south of the stairway, was the now buried platform of the original West Annex. Later this platform was enclosed within the present platform of the West Annex, which also covers the southern end of the platform of the lower stairway leading to the first terrace of the Caracol. On top of this first unit was built the circular substructure with its partially encircling bench, found this year, and the Caracol tower. Next, the western section of the upper platform was built. This terrace had an east and west depth of approximately 22 feet, the northern and southern extensions of the east wall abutting the circular substructure. Finally, this latter platform was enlarged so as entirely to enclose the circular platform.

There still exists some uncertainty as to the chronological position of the small platform or altar between the double stairway leading to the upper platform. This is surely earlier than the first, or western section of the upper rectangular platform, but it may not be earlier than the circular substructure.

Report of Harry E. D. Pollock on the Casa Redonda (Station 15)

During the season of 1928, the reconnaissance work of Karl Ruppert resulted in the discovery of a circular building situated about a kilometer east of the hacienda.¹ With the Caracol as the center of major operations this year, it seemed advisable that some work should be carried on at this round building, in the hope of shedding further light upon structures of this character. As the building was small and appeared to be of no unusual architectural merit, it was planned that excavations should be carried on only to the extent of exposing major features of plan and construction. With this program in view, work was begun early in April and continued for three weeks, the time being divided practically equally between excavation and repair.

After felling the bush, but before any dirt was turned, the mound presented the following appearance: A pyramidal substructure, that might be either round or square, roughly 50 feet in diameter, with traces of a stairway on its west side, surmounted by a circular superstructure approximately 25 feet in diameter, with short stretches of cornice showing on the north and south sides, and a depression, indicating a doorway, at the west. The

¹ See Year Book No. 27, pages 306, 307.

wall of the superstructure apparently stood to a height of 3 or 4 feet, and was battered; immediately above this was the cornice. Finally, the character and disposition of the debris suggested a flat roof of lime plaster supported by beams, rather than the usual corbelled arch type. No bevelled roof-stones were in sight.

Excavation presented no difficulties, and was accomplished by first clearing the interior of the building and subsequently laying bare the exterior wall as far as was thought necessary. Later, trenches were driven into the substructure along one side of the stairway, and a portion of the retaining wall of this was exposed. During excavation a fair amount of corbelled arch stones and a few cap-stones were encountered, but, on the whole, not sufficient to justify the assumption that the building had originally carried a corbelled arch roof.

As mentioned above, the structure was not completely excavated, but the ground plan is approximately as follows: the substructure consists of a round platform 53 to 54 feet in diameter at the base, and varying in height from 11 to 13 feet, due to the fact that the ground level is lower at the rear of the building than in front. The structure faces west, where a stairway, flanked on either side by a low bench, gives access to the summit. The wall of the substructure is slightly battered. The building on this platform is also circular with an interior diameter of 23 feet and an exterior diameter of 30 feet. It is approximately concentric with the substructure, and the base is battered to a height of 3 feet, with a cornice immediately above. The outer doorway is 10 feet wide, having a low step 3 inches high across the front, which served as a sill, the interior floor being slightly above the level of the terrace floor outside.

Inside the building and facing the single exterior doorway, there is a wall running north and south, forming a chord across the interior. This chord subtends an arc of approximately 120° with the outer doorway which is approximately in the middle of the subtended arc. The building is thus divided, so that one-third is occupied by the front chamber and two-thirds by the rear chamber.

A doorway at the middle of this partition gives access to the interior chamber, at the rear of which there is a low stone construction suggesting an altar, while at the true center of the building, and thus also within the rear chamber, there is a small pit sunk into the floor. This pit, which measures 2 feet 8 inches across and 8 inches in depth, is duodecagonal in shape, has vertical sides made of stone, and the remains of plaster flooring at the bottom. Several pieces of obsidian and flint, a number of pot-sherds and a layer of ash were found at the bottom.

Aside from this material, and an obsidian flake, found near the altar against the back wall, the building was unproductive of artifacts, although it yielded a fair number of pot-sherds.

Repair was confined entirely to work of a preservative nature. Walls were strengthened and capped as they stood, a few cornice stones were replaced, and the door jambs were set up and straightened where necessary. In addition to this, a part of the north wall of the stairway was reset and capped, while two of the balustrade stones were realigned and set in mortar.

The balustrade stones have probably not been returned exactly to their original positions; further excavation of the stairway would have been necessary to determine this point definitely, but it appeared advisable to reset these stones for the present, to prevent further deterioration.

This building gives the impression that little craftsmanship went into its construction. The stone is for the most part poorly dressed, and much of it is evidently re-used material. The only sculpture found is on the balustrade stones, which are apparently re-used pieces of door-jambs or pillars, and the relief is quite without meaning in its present position. The conclusion is reasonable, indeed inevitable, that this building is very late.

With the established astronomical significance of the Caracol in mind, a number of azimuths have been taken at the Casa Redonda in the hope of discovering a similar significance for this building. While some of the readings are suggestive, further observations and revision of data will be necessary before the definite astronomic function of the Casa Redonda may be regarded as proved.

Report of J. O. Kilmartin on Information Surveys at Chichen Itzá

The plan and purpose of the information surveys at Chichen Itzá during the 1929 field season were to bring under more direct control and observation the area to the south of the central group of ruins, commonly known as Old Chichen; and to connect this area with the map of the central group surveyed by the writer in 1924.

In carrying out this survey the method used in mapping the various archæological remains was the same as that adopted in 1924 on the survey of the central area of Chichen Itzá. The plane table was used to decided advantage and the control to support the map and hold it in position was obtained by triangulation from two measured bases in the plaza in front of the Castillo, and extended from these stations and others established on the most prominent ruins to the most distant corners of the map in each direction. Fourteen stations were established within the area mapped, the majority being flags fastened to the tops of trees.

It was necessary to wait until all surveys had been completed before attempting any triangulation on account of the density of the bush and the unknown, even approximate position of mounds, ruins or natural elevations which could be utilized as flag and observation stations. The region is devoid of conspicuous topographical features, being a rather flat limestone plain, scarcely more than an hundred feet above sea-level at its highest point in the center of the peninsula. Transit traverse for control was impractical, chiefly due to the difficulty in obtaining sufficiently trained native assistants for accurate work. Ten of the stations were occupied, while the remaining four were located by two or more angles from known stations. Even with the unsatisfactory procedure of establishing control after all sketching had been completed, the results obtained by magnetic needle for orientation, and tape and stadia for distance, are well within the limit of error demanded.

Observations on Polaris were taken and the magnetic declination determined as 6° 40' East. The secular variation over the five-year period, 1924-1929, amounted to 20 minutes of arc.

Positions along the center of the south edge of the map of the central area established in 1924 were used as starting points for the new work.

The general plan was to cover the territory on a grid base, lines being cut at intervals of 200 feet in each direction—north, south, east and west, working in a circuit west, thence south, east and north, back to the point of beginning. The scale adopted, 200 feet to one inch and contour interval of 5 feet, was the same as that used in the map of the central area, made in 1924. In order to make the survey it was necessary to cut lines through the bush to the extent of 30 miles.

The geodetic coordinate of the Castillo and the elevation of Dzitas, upon which the map is based, were very kindly furnished by Senor Ing. Don Pedro C. Sanchez, Director of Geographical and Climatological Studies of the Mexican Government, taken from Publication No. 8 of that bureau.

A line of stadia levels was carried from Dzitas (C.F. 15—Clavo de bronce—27.288 metros—89.504 feet) 20 kilometers to the assumed datum plane at the western base of the Castillo at Chichen Itzá and to convert the elevations and contours, shown on the map to sea-level reference, 9.50 feet should be added.

As a result of the survey 264 archæological remains were definitely located and brought under observation. These may be classified according to their relative importance, and to some extent their use as well, as follows:

I. Temples having chambers of corbel arch construction in which ground-plans could be worked out from existing surface indications. Structures of this group are shown on the map by heavy black lines corresponding to their probable ground-plans, and are drawn to scale, there being very little doubt as to their actual dimensions. In most cases these structures have columns, either round or square, and with very few exceptions are without sculpture. Surprisingly satisfactory results in reconstructing the original ground-plans may often be obtained by noting the position and shape of certain stones. Often in structures of this class the entire ground-plan may be worked out from such simple points as the position of a few cut stones in line, from stones which form right angles and from the presence of corbel-arch stones, which are only found, when *in situ*, above the spring of the arch. Columns serve as the best guides in reconstructing ground-plans. Large scale drawings of all groups in this class having columns were made and later reduced to the field scale of the base map.

II. In the second class of remains, the original structure has been so completely destroyed that it is quite impossible to reconstruct satisfactory ground-plans. A symbol denoting an elongated pyramid is used to designate structures of this type on the map.

III. In the third class, which is the most numerous, are included such remains as platforms, altars, parapets and terraces. Single dashed lines are used to designate these remains. Such platforms and terraces were doubtless used by people of the humbler classes as foundations for their simple houses of poles and thatch, such as are used today throughout Yucatan, especially in the smaller villages. There is not sufficient masonry debris on terraces of this class to indicate the former presence of stone buildings.

IV. In this group are placed *chultunes* (cisterns), *sacbeob* (causeways), and stone walls, although the last are not designated on the map.

Five *chultunes* were located, all of which are in good condition, no new features being noted in their construction. One fairly long *sacbe* was followed from its beginning at the southwest corner of the Monjas to its terminus at the Temple of the Four Lintels. These two structures date from 1019 and 1014 A.D., respectively, exactly five years difference in age. It is not straight, as had first been supposed, but follows a somewhat winding course, taking advantage of the topography in making easy grades and gentle curves.

Two other *sacbeob* (causeways) were followed from their points of beginning, but could not be continued to their termini, due to the fact that they were destroyed beyond possibility of identification. There were no structures in line or nearby at which these causeways might possibly have ended.

Only stone walls of considerable length and of apparently special significance have been shown on the map. No explanation can be offered at this time as to the purpose of the hundreds of low stone walls which run apparently aimlessly from terrace to terrace, over mounds, across temples and out into flatlands, although they probably date for the most part from pre-conquest times.

It is now known that the Maya took advantage of every hill or elevation of any size on which to construct their houses and temples. Perhaps in addition to elevating their temples for ceremonial purposes, they desired to locate their dwellings away from the lowlands, which tended to gather and hold water during the rainy season and were correspondingly less healthful. The topography partly explains the concentration of construction in a general southwesterly and northeasterly axis.

The southeast portion of the area is practically devoid of constructional remains, although it contains one architectural unit of importance—the Group of the Hieroglyphic Jams. There is no visible water supply for this group and should there be a well in the bottom of the dry *cenote* adjacent, it is now filled with debris.

As yet no astronomical rule has been discovered which governs the orientation of Maya structures. Observations on twenty buildings of Class I, on which definite construction lines could be determined, show that their longer axes (taken usually along the front façade) vary in azimuth from 187° at the Monjas to $212^{\circ} 30'$ at the Temple of the Two Lintels, reading from the south dextrally. Temples facing the east are few in number. Most of them face in a westerly direction; while a few face north; none has been found as yet facing south.

There is reason to believe that some astronomic phenomenon may have determined the orientation of Maya structures. In view of the relatively consistent orientation of so many different and widely distributed architectural units, it is hardly conceivable that the Maya were able to achieve such uniformity in orientation over such a large area, without some definite rule to guide them.

The area covered by the information survey is slightly less than one square mile, being 5,200 feet east and west by 4,800 feet north and south.

In addition to the new survey, a revision was made of the major groups of the map of the central area, covering the progress made by the Institution during the first five years of its excavation program. This revision

includes exact ground-plans of the Temple of the Warriors, the Northeast Colonnade, the Temple of the Xtoloc Cenote, the Temple of the Interior Atlantean Columns, the House of the Corn Grinders, the Caracol and its Annexes, and the Temple of the Wall Panels. All of these revisions have been made on a large scale and then reduced to the scale of the large sheet. They will appear on the new map, which will include all the data obtained both in the 1924 and 1929 surveys.

Solar observations, taken from the axis of the central doorway of the Temple of the Warriors to the southwest corner of the Temple of the Jaguars, showed the semidiameter of the sun to bisect the horizon, the summit of the east wall of the Ball Court and the southwest corner of the Temple of the Jaguars at an azimuth of 108° on April 12 at 6^h 21^m 40^s p.m., 90th Meridian time.

Observations on the planet Venus for heliacal setting through the west doorway of the outer corridor of the Caracol proved inconclusive, due to the smoke of burning cornfields which obscured the horizon and greatly reduced visibility. It seems probable that Venus may have set at an angle slightly north of west on or about April 18, since on June 3 the planet was observed as Morning Star at an angle of about 15° north of east at 2^h 45^m a.m.

Report of Miss Katheryn MacKay on the Chichen Itzá Clinic

The Chichen Itzá Clinic was open from January 4 to July 10 during the 1929 field season. Within a few days after its opening the Maya began to flock into Chichen Itzá from the surrounding country, whole families at a time. The influenza epidemic had just reached Yucatan and the Indian population was very generally affected.

Owing to the limited space available for the Clinic—a single room where only three bed-patients could be accommodated at one time—only the most serious cases could be given continuous attention and treatment. At the height of the epidemic, an outlying thatched hut was pressed into service as a temporary though inadequate hospital. In these places the worst cases were handled; the others were given medicines with instructions how to take them, and sent home to treat themselves. A number of villages sent runners to Chichen Itzá for medicines, which were distributed, free of charge, until the supply was exhausted.

The epidemic was not particularly malignant—out of nearly 300 cases treated, only 8.5 per cent had bronchial pneumonia, and of these only one died. The pneumonia cases were cared for as bed patients at the Clinic.

The Clinic drew patients from a radius of about 50 miles, many Indians walking long distances for treatment, mothers with babies in their arms, small children, even old men and women.

A total of 624 cases was treated during the season as shown in the following table. Most of these were cared for in the central Clinic at Chichen Itzá, but in addition outside clinics were held in the neighboring villages of Pisté, Xocenpich, Dzitas, Yulá, Nietehá, Chankom and Kaúa.

The foregoing table requires little comment. In view of the epidemic proportions of influenza this season it is not surprising to find that nearly

half of the cases treated (47 per cent) were for this disease alone. Dysentery and colitis come next with a total of 20 per cent. Diseases of malnutrition such as pellagra and scurvy rank third with a total of 12.66 per cent, and ophthalmia is fourth, 5.5 per cent of the cases suffering from eye infections.

Chichen Itzá clinic report, January 4 to July 10, 1929

Children		Adults	
Diseases	Number of cases	Diseases	Number of cases
Influenza.....	105	Influenza.....	165
Influenza complicated with pneumonia.....	15	Influenza complicated with pneumonia.....	10
Dysentery and colitis.....	75	Dysentery and colitis.....	50
Ascarus.....	10	Ascarus.....	5
Whooping-cough.....	10	Malaria (active).....	10
Scurvy.....	4	Pellagra.....	75
Ophthalmia.....	25	Ophthalmia.....	10
Skin infections.....	25	Accidents.....	30
Total.....	269	Total.....	355
Grand Total.....		624	

The very few cases of malaria treated is probably due to two factors: (1) there is very little malaria around Chichen Itzá itself, most of the cases being brought in from the outside, and (2) the Clinic was open only during the dry season. A report of the same number of cases drawn from the same region for the last half year—July to January, *i.e.* during the rainy season—would undoubtedly show a much higher percentage of malaria.

Finally, it should be noted that practically 100 per cent of the population, both children and adults, show *Ascarus* infection, although very few are clinical cases—less than 2.5 per cent during the 1929 season.

Report of O. G. Ricketson jr. on the Excavations at Uaxactun

In conformity with the contract granted by the Government of Guatemala to the Carnegie Institution of Washington for the excavation of the ruins at Uaxactun, the fourth season was inaugurated early in January. The expedition consisted of Oliver Ricketson jr., in charge, A. Ledyard Smith, assistant archaeologist, Edith Bayles Ricketson and Enrique Shufeldt, field assistants.

Although Mr. and Mrs. Ricketson arrived in Belize, British Honduras, on January 9, it was not until February 7 that they, accompanied by Mr. Shufeldt, were able to leave for El Cayo and the ruins. This delay was due to the chaotic transport conditions prevailing in the Department of Peten, Guatemala, as the result of the cessation of work in that district by the P. W. Shufeldt Co., on which previous expeditions had depended for the

transportation of supplies. It was finally necessary for the expedition to purchase ten pack mules, to add to the ten animals already owned, and to organize its own pack train.

Upon his arrival in El Cayo, Mr. Ricketson called officially upon the Guatemala Customs authorities at Fallabon, to present his credentials. The expedition arrived in Uaxactun on February 20, and on February 25, after the necessary clearing of the ruins and repairs to the field headquarters had been completed, the excavations in Group E were resumed.

The season's work may be divided into four parts:

- I. Excavations in Group E.
- II. An examination of the stelæ, to determine possible relationships between stelæ and plaza floors, stelæ and temples, and to look for sub-stela caches.
- III. A map of the environs of Uaxactun, to determine the number, frequency, locality, and possible relations to each other, of house-mounds and chultuns, for the purpose of estimating the population.
- IV. Miscellaneous excavations.

Before proceeding with the description of the excavations in Group E,¹ the following additions to the nomenclature used must be noted:

1. The East Mound: the platform mound, 15 feet high, upon which stands Temples E-I, E-II, and E-III; this mound bounds the east side of the plaza of Group E.
2. The South Mound: the platform mound, 16 feet high, upon which stands Temples E-IV, E-V, and E-VI; this mound bounds the south side of the plaza of Group E.
3. Structures A, B, and D: ill-defined constructions encountered below one or more plaza floors; they are probably low platform mounds upon which stood former buildings which were demolished during the enlarging of the plaza of Group E.

The object of the excavations made in Group E during the past season was to determine the character and relationship of the four floors uncovered during the previous season.² To this end, two main trenches were dug in the plaza, one running east and west across the plaza just north of Stelæ 19 and 20, and the other running north and south approximately in the center of the plaza. With the intersection of these two trenches considered as the central point, the trenches extending from this point were called the North, East, South and West Trenches, respectively. All of these trenches, except the West Trench, were started from pits sunk on the edges of the plaza, Pit 3 in the North Trench, Pit 8 in the East Trench, Pit 17 in the South Trench; the trenches then being dug toward the center, 10 feet wide on the surface and following the topmost floor that had appeared in the pit. When it became evident that this system would not be satisfactory, since the top floor in some cases disappeared entirely or proved to be only

¹ See Year Book No. 27, page 307 et seq.

² Cf. Year Book No. 27, page 313.

a terrace level, the trenches were dug from the center pit toward the edges of the plaza, still clearing only one floor at a time. This procedure was adopted to preclude the possibility of a careless workman mixing sherds from different strata. Narrow ledges of each floor were left extending into one side of the trench, and these ledges proved to be of the greatest assistance in solving the problem presented by the extremely complex system of floors, repair floors and terraces.

The East and West Trenches, whose combined length was only 122 feet, as compared with 256 feet for the combined length of the North and South Trenches, were completed first. A cross-section shows six distinct floors in the central area, the bottommost being called Floor 1 and the topmost Floor 6. Eastward from the central pit these floors slope up gradually, approximately 0.21 inches per foot. Floor 1 lies at a depth of 42 inches below the surface, and Floor 6 at a depth of 11 inches. Judging from the quantities of small stones, about the size of English walnuts, that overlie Floor 6, it is probable that there was once another plaster floor above Floor 6, as the Maya, in Uaxactun at least, often laid their plaster floors on a foundation of coarse gravel. Floors 3, 4, 5 and 6 are relatively closely laid, one upon another, but Floor 2, the plaster surface of which is 2 inches thick, lies on a gravel bed 6 inches deep in the center of the plaza and diminishing toward the west. From this gravel bed great quantities of sherds were recovered.

Toward the western end of the West Trench, almost directly in front of Temple E-VII sub, a stone retaining-wall about a foot high was encountered. This wall was found to be contemporaneous with Floor 1, *i. e.* Floor 1 did not continue under the retaining wall but turned up to meet it in such a way that it could be inferred that the retaining wall was built and the floor laid at approximately the same time. Wing trenches to follow this wall were dug, and the structure, which is called Structure A, proved to be a simple platform, the outlines of which can be traced distinctly on the north and east sides. Of the west and south sides only portions remain *in situ*. Probably the missing portions were removed in order to utilize the stones in the building operations incident to the expansion of the plaza or in the erection of Pyramid E-VII sub itself. Floor 2 ends against the retaining wall, but Floor 3 and all floors above it pass over Structure A. In this vicinity, Floor 1, gradually sloping up, apparently, coalesces with Floor 2. Floor 3 is flush with the terrace-like foundation of Temple E-VII sub; viewed from above the terrace and the floor would appear to be one, but in a cross-section view the terrace turns down and Floor 3 joins it. This type of construction was found elsewhere during the season's excavations, and the excavator must constantly be on guard against confusing terraces and floors that join on the same level; obviously, the pavement in these cases is a later construction.

It was discovered that the Floor *a* referred to in the report of last year's work¹ was actually the above-described temple terrace, and would therefore correspond to Floor 3. Similarly, Floor *d* corresponds to Floor 6, Floor *c* to Floor 5, and Floor *b* to Floor 4.

¹ Year Book No. 27, page 313.

A re-examination of Stela 20 was made, and it was found that this monument, bearing the date 9.3.0.0.0 (235 A.D.) must be associated with Floor 6. Stela 19, bearing the date 8.16.0.0.0. 3 Ahau 8 Kankin (97 A.D.) on the other side of the plaza, is also associated with the topmost floor. Obviously, one of these monuments can not be in its original position, if we suppose that the dates cut upon them are synchronous with their erection. Conversely, if both monuments are in their original positions, the date on Stela 19, since it is the earlier, must have referred to some past event at the time when it was erected. It is the writer's belief that one or both of these stelæ have been moved from their original positions.

The East Trench, viewed in cross-section, shows six floors near the central area, but toward the eastern border of the plaza another floor appears between Floors 4 and 3. This is called Floor 3', and the exact point of its beginning could not be discerned. Floor 3, 32 feet west of the first step on the East Mound, sloped upwards to coalesce with this extra floor and continues as Floor 3' to the East Mound. It would therefore appear that the plaza was widened some time after laying of Floor 3 and previous to the laying of Floor 4. Floor 4 runs under the East Mound, secondary construction. A narrow trench dug into the East Mound revealed a primary construction immediately inside; this was of stucco over a stone core and consists of 13 steps or terraces reaching the top of the East Mound.

A double row of large squared limestone blocks was uncovered, 22.5 feet west of the East Mound, running north and south across the East Trench. Their function could not be determined, but it is tentatively suggested that they represent blocks taken from a demolished building and re-used as fill for leveling purposes during a period when the plaza was being extended.

Of the South Trench the space available in this report permits only the most cursory description. Seven distinct lines of stones were encountered, two of them double, running east and west across the trench. Wing trenches to determine the extent and function of these lines of stones were ineffectual, except in the case of the two most southerly rows. The southernmost row appears to be a low retaining wall with a batter. It could be followed to a corner on both the east and the west, where in each case the wall turned north. The northeast corner of this structure, Structure D, could also be determined, but within a few yards of the corner the north wall was permanently lost under the roots of a gigantic Spanish cedar. The northwest corner was found symmetrically placed opposite the northeast corner, but within a few feet of it the north wall again disappeared. There seems to be sufficient evidence, however, together with the evidence produced by the next most southerly row of stones, which resembled the wall of an inner room, to describe Structure D as a platform mound with cut-stone, battered retaining walls, upon which had stood a building.

The South Trench was continued into the South Mound. Little trace of the secondary construction remains *in situ* here, but evidence of primary construction abounds. The northwest and northeast corners of the mound were determined, but further excavation will be necessary to decide whether the small sections uncovered should be classed as primary or secondary. Both corners are rounded, not square, and the blocks composing the walls

are massive and well cut, leading one to infer they belong to the earlier construction.

By far the most complicated labyrinth of retaining walls, floors, and re-used walls of demolished buildings was uncovered in the North Trench and the extensive excavations that developed from it. Briefly, the salient features may be described as another low platform mound, Structure B, which apparently had either a lower platform projecting from it on the south side, or was partly superimposed on another and earlier platform mound. Further excavation is necessary here. Floor 1 ends against the bottom of the projection on the south side of Structure B. Floor 2 coincides with the top of the same construction. Floors 4, 5 and 6 pass completely over the whole north half of the plaza. Mound E-VIII, secondary construction, extends in terraces into the plaza, some of the terraces coinciding with or terminating against retaining walls of Structure B. No less than five excellently preserved floors pass completely under Mound E-VIII. Upon trenching into this mound, primary construction was encountered almost immediately, leading to the top in nine steep terraces. As these terraces were too high to step up comfortably, a single cut stone had been placed against each riser as a step. Three such stepping-stones were found *in situ*, the mortar in which they had been set still being present. The construction of Mound VIII sub (terraces of well-cut stone heavily coated with stucco) is exactly like that of Temple E-VII sub and the primary terracing on the East Mound. A narrow trench was dug through the facing of Mound E-VIII sub into its core, and continued until its face, perpendicular with the front edge of the top of the mound, measured 22 feet in height. The core of the mound was found to consist entirely of very large uncut pieces of limestone embedded in a hard marl, and the removal of these boulders from the 22-foot face required so much effort and entailed such risk that the work on the trench was discontinued. There was no evidence that Mound E-VIII sub contained within it any earlier construction; however, as this trench had been dug because a pit on the outer edge of the mound showed five floors passing beneath it, another pit was sunk at the end of the trench and the same five hard floors were encountered, suggesting that any interior structure might conceivably lie beyond the limits of the trench.

Temple E-VII sub, uncovered during the past season, was examined more closely, with special attention to its relation to the various plaza floors. This study proved very puzzling. Floor 2, with which Floor 1 had coalesced just east of Temple E-VII sub, continued under the pyramid on its east side, but a short trench up to the pyramid on its west side indicated that no floors ran under it there. To explain this difference, a painstaking examination of the floors around the north side of the pyramid was undertaken, but the confusion was so great that no satisfactory results could be obtained. Then a narrow trench was dug into the north side of the pyramid, cutting through the north stairway. At this point two floors ran under the temple and two ended against its base. The topmost of these four floors could be identified as Floor 5; the other three could not be connected actually with known plaza floors, though they checked correctly, counting downward, with Floor 4, Floor 3, and the coalesced Floors 2 and 1.

This trench exposed the heavy stone veneer of Temple E-VII sub, and 9 feet in from the bottom step a crudely laid terraced wall appeared, rising in eight terraces to a point 20 feet directly under the platform mound on top of the pyramid.¹ Whether this crudely laid structure is merely a core upon which Pyramid E-VII sub stands, or is an independent structure over which E-VII sub was built, it is not possible to say at the present time and further investigation will be necessary. Two points should be noted here: the two floors running under Pyramid E-VII sub definitely continued underneath the interior structure; and the fill between this interior structure and the stone veneer of E-VII sub is radically different from the fill encountered within Mound E-VIII, in that it is composed of irregular but distinct strata of soft white marl, gravel and black clay.

Twenty-eight pits were sunk in the plaza of Group E, of which the more important may be briefly described as follows:

Pits 1, 4, 15 and 18 were dug in the northwest, northeast, southwest and southeast quarters of the plaza, respectively, to determine the depth to undisturbed soil. Pit 1 pierced 3 floors and was dug 5 feet 11 inches deep; it was left incomplete still penetrating disturbed strata. Pit 4 pierced 4 floors and was dug 10 feet 4 inches deep; it was left incomplete, still penetrating sherd-filled ash and charcoal. Pit 15 pierced 4 floors and struck bedrock limestone at 8 feet. Pit 18 pierced 4 floors and was dug 7 feet 2 inches deep through disturbed strata, finally striking large stones; it was left incomplete at this point. A charcoal and ash deposit was encountered at 5 feet 2 inches from which artifacts were obtained, including bone awls and needles, crude flint implements, etc.

Pit 9 was dug in the bottom of the East Trench near the center of the plaza, to a depth of 9 feet 9 inches. At 5 feet 11 inches stiff fine black clay was encountered, and below this, at 8 feet 1 inch, a 7-inch stratum of small limestone broken gravel full of sherds.

Pit 20 was dug in the center of the North plaza of Group E. It pierced 7 floors and at 7 feet 8 inches reached undisturbed black clay.

Pits 12, 13, 14 and 28 were dug west of E-VII sub, primarily to determine how far various floors extended westward from the plaza and the depth to bedrock at various points. Floor 5 ended 11 feet 6 inches west of E-VII sub; Floor 3 ended 16 feet west of E-VII sub in Pit 12, which was dug 4 feet to bedrock; Pit 13 reached bedrock at 2 feet 8 inches; Floor 2 ended 39 feet 6 inches west of E-VII sub in Pit 14, which was dug 2 feet 6 inches to bedrock. Pit 14 also exposed a badly preserved skeleton, lying on solid limestone, head to the north and face down, at a depth of 2 feet 6 inches. There was no funerary furniture and the skeleton could not be recovered.

Pits 3, 8 and 17 were dug as starting points for the North, East and South Trenches, respectively. Pits 7, 10 and 11 were dug during the previous season,² Pit 7 just north of Stela 18 (Trench No. 3 in the report of that year), Pit 10 east of Pyramid E-VII sub (Trench No. 1 in the report) and Pit 11 north of and under Stela 20 (Trench No. 2 in the report). The nomenclature is here changed because this season's excavations, removing

¹ Year Book No. 27, page 310.

² Cf. Year Book No. 27, pages 312, 313-317.

all the upper dirt, completely obliterated the trenches, which were really in the nature of pits.

As a result of the excavations in the plaza of Group E, I believe it is safe to make a few general observations, though the excavations are still incomplete. The complex of structures called Group E appears to have gone through no less than four distinct periods:

- I. First occupancy—ash-pits and rubbish heaps formed.
- II. Erection of the earliest platforms—Structures A, B, D.
- III. Demolition of earliest buildings, expansion of plaza, and erection of the "Primary type" structures—Pyramid E-VII sub, etc.
- IV. Erection of the "Secondary type" structures *over* the "Primary type" buildings—Pyramid E-VII.

So far, no mention has been made of the pottery found at Uaxactun and at this writing there is little to be said. Permission has been obtained from the Government of Guatemala to transport all portable objects to Guatemala City, where Messrs. Ricketson and Smith will take up a residence in order to make an intensive study of all sherds. It is possible, however, to make the following general statements, subject to later corrections:

1. No polychrome pottery occurs below the topmost floor of the plaza (Floor 6).
2. Few sherds of any description occur between Floors 6 and 2.
3. The sherds from the deep gravel layer beneath Floor 2 occur in great numbers and are characterized by: (a) polished red or black slip; (b) horizontal fluting, and some vertical fluting; (c) simple silhouette, vases and dishes.
4. Sherds from beneath the bottom floor (Floor 1), in the so-called "Black Dirt," are of the following types: (a) Human effigy figurines, characterized by extreme simplicity, free-hand modeling, grooved and punched eyes and nipples, rolled fillets around the head, and relative flatness antero-posteriorly. The figurines are all represented as standing rigidly, the legs formed of one piece, down the center of which a groove indicates the line of separation. Not more than a dozen and a half fragments of figurines of this type were found during the season. (b) Animal effigy whistles; of these only fragments were found. (c) Shards of highly polished red or black-ware, incised after firing with parallel lines and in geometric patterns.
5. In Pit 4, in the ash deposit at the bottom, was found a figurine's arm and shoulder of sun-baked clay with a light-brown slip, dull polish.

The above classification attempts no more than the noting of types which appear to be characteristic of their respective strata. Types of pottery occurring more generally are omitted, as are the finer gradations impossible to determine until all the specimens have been thoroughly cleaned and examined.

Report of O. G. Ricketson jr. on Miscellaneous Excavations

(1) A burial was found in the center room of Structure E-X, lying head to the north, face up, in a shallow grave that had been dug through the two lower floors. Two upper floors covered it. The skeleton was that of a male, the skull showing slight occipital flattening. The facial portions had disintegrated; although the mandible was recovered, only ten teeth were found. The skeleton lay on its back, the left arm across the abdomen, the right so flexed that the hand rested on the right clavicle. The pelvic region was filled with ash and charcoal, and from the waist down the body lay more nearly on its right side, the left knee half-flexed and lying over the right. The objects found with the skeleton were all placed around the head; these consisted of four pieces of bone, two shell disks, one shell ring, one annular shell lip-plug with small pits cut on the anterior surface, one whole shell with four perforations, one piece of shell and half a mandible of a carnivorous animal with the end cut off smoothly.

(2) Five pits were dug in Group A, around Temple A-V, Pit 1 to the west, Pit 2 to the north, Pits 3 and 5 to the east and Pit 4 to the south. Pit 1 pierced a floor at 1 foot 6 inches and struck blue clay at 4 feet; Pit 2, 4 feet 6 inches deep, pierced a floor at 1 foot 4 inches and struck marl at 2 feet 6 inches; Pit 3, 4 feet deep, pierced a floor at 1 foot and struck marl at 2 feet; Pit 4, 3 feet deep, encountered no floor and stopped at bedrock; Pit 5, 3 feet 6 inches deep, pierced a floor at 10 inches and another at 2 feet 2 inches which overlay 10 inches of dirt and limestone, and 6 inches of burnt lime, black dirt and small pieces of unburnt lime. Pit 4 yielded a three-legged flat dish of red ware, with rattle legs. Two trenches were dug into the slope north of A-V, to determine whether the apparent talus slope from the artificial retaining wall along the top of the hill had been formed by refuse from the complex group of buildings above, but this slope was found to be composed of solid limestone under 1 foot of vegetable humus.

Report of A. Ledyard Smith on the Investigation of Stelæ

An investigation of the stelæ at Uaxactun was started on April 1. The purpose of this work was threefold: first, to associate dated monuments with adjoining plaza floors and temples and to determine the reliability of dating the temples by this means; second, to determine the methods used to erect and support the stelæ; and third, to discover possible caches under the monuments.

There are 44 stelæ in Uaxactun. They are, of course, in different states of preservation, some still standing, others broken off at ground level with bases *in situ*, and some completely uprooted. No study was made of the uprooted stelæ, as it proved impossible to find the holes in which they originally stood. Of the 44 monuments, all but 7 were examined. Sixteen were still standing, and 10 were broken off at ground level or slightly above, with their bases still *in situ*; 11 were found uprooted.

This investigation shows that it is not possible to date definitely a temple by the date of the monument in front of it. Generally the floor is broken around the base of the stela, and this condition may be due to the shifting of the stela or to the action of water running down its sides. It may also

indicate that the monument has been set through the floor and is therefore of later date than the floor. Even when the connection is perfect and the floor turns up to the monument and is definitely joined to the temple behind it, one can only say that the temple is probably contemporaneous with the stela. Conclusive evidence that many of the stelæ were moved and re-used makes any positive dating of the buildings by means of the stelæ unreliable at Uaxactun.

Stela B5, in B group, will illustrate this point. This stela, of fine hard limestone, was absolutely plain from the floor level up; no traces of carving could be found. Upon close examination, carving was discovered just below the floor level, and one could plainly see that the stone had been chiseled down to remove the carving above the floor level. The carving consisted of a glyph panel, much obliterated, extending to within 8 inches of the base of the stela. Thus the present base of the stela might originally have been the top. Another example is the altar of Stela 9 at Group A; this altar was made from a carved stela (No. 10), and part of the original design may still be seen on the top and bottom. Still another example is to be found at Group E, where an examination of floor conditions seems to indicate that Stelæ 18 and 19 were set up after Stela 20, which bears a date later than that on 18 and 19.

There were five methods of supporting the monuments. The most common was to place the stela in a hole from 1 to 3 feet deep and hold it in position by wedging small stones around the butt and filling with a fine rubble composed of burnt lime, small stones and dirt. A second, frequently used when the stelæ were set through floors or required additional support, consisted in building a platform around the stela above the top floor. Stela 4, in B group, illustrates this very clearly. A third method was to build the stela into the wall of another structure; thus the base of Stela B1 is held in position by the stones of the lowest terrace of Temple B-V, the butt of the stela extending only six inches under the floor. A fourth method consisted in building a stone crib below the floor to receive the butt of the monument. There are three examples of this method of support at Uaxactun, namely Stelæ A6, 6, and A10. These cribs in no way suggest vault construction; they are not nicely fitted, and are made of roughly cut stones. The fifth and most effective method consisted in cutting a hole, 1 to 2 feet deep, in very hard marl and shaping it as nearly as possible to the butt of the stela. Between the stela and the marl is tamped a mixture of burnt lime and dirt which acts as a cement.

Caches were found under six of the monuments, and were of three types: (1) eccentric flints, shells, and worked objects of shell, jade and obsidian; (2) flint and obsidian chips, mixed; (3) obsidian cores and chips, no flint.

The first cache was found under Stela 4, and contained the following objects: 8 eccentric flints, 3 "bat with spread wings" shape, 3 "snake" shape, 2 "deer-head" shape, 3 eccentric obsidians, "deer-head" shape, 1 obsidian core, 2 small obsidian blades, 1 jade bead, polished but not drilled, 5 small jade chips, 1 small, flat jade figurine, 2 small, flat shell figurines, 2 pieces of carved conch shell, 2 pieces of coral, 2 small pieces of mineral, probably iron pyrites. These objects were not in a cist, but were found scattered in the rubble under the southwest corner of the monument. The eccentric

flints are very similar to those found at Baking Pot;¹ they are probably conventionalized animal forms used with some religious significance.

A cache of similar type was found under Stela A11. It contained the following objects: 6 eccentric flints, 4 "snake" shape, 2 "deer-head" shape, 2 "laurel leaf" flint blades, 2 obsidian cores worked to a point at each end, 2 obsidian cores (possibly eccentric obsidians), 4 obsidian chips, 1 sea shell (scallop ?), 1 piece of shell. The flint objects were found around the edges of the monument, and the obsidian and shell beneath its center.

Another type of cache was found under Stela A6. This consisted of 41 obsidian cores, some pointed at each end and others comb-shaped with three teeth; with these was a great quantity of chips and broken obsidian blades. A similar cache was found under Stela A7, containing 30 obsidian cores of the above-noted types and many obsidian chips.

A third kind of cache was found under Stelæ B2 and A1. Here very little obsidian was found but a great many flint chips, obviously the result of the manufacture of flint implements, were mixed with the dirt under the monuments.

A most unusual find was encountered under Stela 17. Here, under a floor and 6 inches from the base of the stela was the mouth of a chultun covered by a flat, circular stone. This chultun had two chambers, one a little to the north and below the other, directly under the stela. Nothing was found in either chamber.

The results of this investigation of the stelæ were disappointing in some measure. It has shown that any certain dating of buildings by means of stelæ is impossible, because of the evidence that stelæ could be and were moved and re-used. Although few caches were discovered, they may be considered important, as the objects found in them conform in general to the type hitherto found in sub-stelæ caches and exhibit some new features as well. The methods used to support the stelæ show no striking originality or ingenuity, and seem to have been suggested mainly by the type of soil where the stela was to be placed.

Report of A. Ledyard Smith on the Map of Environs of Uaxactun

On February 25, Mr. Enrique Shufeldt was given the task of mapping the country surrounding the six main groups at Uaxactun. The purpose of this work was to ascertain the number of house mounds and chultuns in the vicinity of the civic center, in order to make an estimate of the ancient population.

The following method was used in making the map: Two main lines of sight were cut, one east and west, the other north and south, crossing each other at a point 625 yards southwest of the main aguada. The north-south line runs through Groups A and B and the east-west line through Groups D and E. Additional lines were then cut parallel to the two main lines and 100 yards apart, and other lines intersecting these at right angles at intervals of 100 yards. The area thus divided into squares is cruciform, each square being 100 yards on a side. The arms of this cross, each 400

¹ See Ricketson, Carnegie Institution Pub. No. 403.

yards wide, extend 1,400 yards to the north, 1,800 to the east, 1,600 to the south and 1,000 to the west of the point of intersection.

After the squares were cut they were numbered and searched. They were purposely made small, because the density of the jungle made it difficult to see the house mounds, and the search of each square had to be accomplished with a minimum of bush cutting.

The Eastern Arm consists of 72 squares, or 720,000 square yards. Of these squares 24 were not searched, as they lay in Group E which had already been mapped. Twenty-nine squares were *bajo*, or low swampy land, and 19 were high ground. Nineteen house mounds and 3 chultuns were found. The house mounds were usually elliptical in shape and were found standing alone, 2 together in an L shape, or 3 or 4 around a court. Sometimes a single house mound was in the shape of an L. The chultuns were not always found in connection with house mounds. All of the house mounds in the eastern arm occur on high ground except in two cases, where large artificial mounds had been built in the *bajo* and house mounds placed on top of them. In the extreme eastern tip of the mapped area a small *aguada* or water hole was found.

The western arm consists of 40 squares, or 400,000 square yards. Of these 39 were high ground and 1 *bajo*. On the high ground 8 house mounds and 4 chultuns were found. In this area the chultuns were not connected with house mounds.

In the northern arm there are 48 squares, or 480,000 square yards. Of these 18 are high ground, 14 are *bajo*, and 16 are in Group A. On the high ground 14 house mounds and 4 chultuns were found.

In the southern arm there are 56 squares, or 560,000 square yards. Of these 38 are high ground and 18 *bajo*. On the high ground, 24 house mounds and 17 chultuns were found. Of the chultuns, Chultun 3 is the most interesting. It should really be called a cave, for although a hole of the same type as those used for chultuns is cut through the surface rock, the inside is a natural cave, about 23 feet long by 18 feet broad by 8 feet high; another and smaller cave can be entered from it through a narrow hole in the southern end and small passages just large enough to crawl into lead off to the north and west. This cave was probably formed by the sinking of the limestone floor, and apparently had been used as a dump, for a great deal of broken pottery was found in it. There is also evidence that it had been used for a long time, because all the types of pottery previously found at Uaxactun were present. Some of the best pottery yet found in Uaxactun came from this cave; in addition to the pottery a beautifully worked "laurel leaf" flint, pieces of human bone, part of a figurine of the flat type, a carved limestone metate and mano, and a broken limestone "comal" were found.

In estimating the density of the population per square mile, the area of land suitable for dwelling purposes must be considered. Of the 2,160,000 square yards under consideration at Uaxactun, 620,000 square yards were *bajo*, swampy land unfit for the building of houses, and 400,000 were occupied by complex groups of temples, courts and pyramids obviously not intended to be dwelling places for the common people. Hence, only 1,140,000 square yards of the area considered are suitable for dwellings; this equals 0.37 square mile, in which were found 63 house mounds. If we

consider the average number of persons in a Maya family living in one house to be seven, this would give us 1,187 persons per square mile of *habitable* land, exclusive of *bajo*.

Report of S. G. Morley on the Piedras Negras Expedition

On May 5, Dr. Morley left Chichen Itzá for the Old Empire center of Piedras Negras, in the extreme northwestern corner of the Department of Peten, Guatemala. The journey was made by sailboat, with auxilliary motor, from Campeche to Ciudad del Carmen, thence up the Usumacinta River to Tenosique, at the head of navigation, and thence by mule train, 40 miles south to the ruins, which are located on the east bank of the river, in Guatemala.

Before publishing on the inscriptions at this site, it appeared advisable to subject them to further examination to clarify moot points, as well as to search for additional monuments, which might perhaps fill some of the few remaining lacunæ in the chronologic sequence of the monuments there.

Dr. Morley was at Piedras Negras from May 5 to May 12 and found 4 new Initial Series and 1 new Period Ending. Through the application of the Teeple formulæ for Glyphs C and D, of the Supplementary Series, it was possible to correct an earlier reading of the Initial Series on Stela 23. The contemporaneous date of Altar 1 was also probably determined. The new decipherments are given below:

Monument	Maya date	Christian era	Kind of date
Stela 15.....	9.17.15.0.0	527 A.D.	Initial Series
Stela 33.....	9.10.10.0.0	383	Initial Series
Altar 3.....	9.19. 0.0.0	551	Initial Series
Altar 4.....	9.18. 0.0.0	531	Initial Series
Stela 18.....	9.17. 5.0.0	517	Period Ending
Stela 23.....	9.14.15.0.0	467	Initial Series
Altar 1.....	10. 0. 0.0.0	571	Period Ending

Although no new monuments were discovered, the missing middle and bottom fragments of Stela 15 were located. Maler had found the top of this monument on his fourth visit to Piedras Negras in 1899, but was unable to locate the remaining pieces. Dr. Morley on his two previous visits to the site, in 1914 and 1921, had even failed to find Maler's top, but this year not only the top was refound, but the middle and bottom pieces as well were located for the first time.

Stela 15 dates from the Great Period of the Old Empire, and is a magnificent example of ancient Maya sculpture, executed at the very moment of esthetic apogee. The relief is so high—8 to 9 inches—that the human figure carved on the front stands almost free of the background, the sections under the armpits being completely cut through and the upper arms appearing in the full round. The head is surmounted by a gorgeous panache of falling plumes; the hands are clasped naturally in front of the figure, holding a bag or pouch upon which is beautifully carved the day "5 Ahau," the day of the Initial Series on the left side, viz, 9.17.15.0.0 5 Ahau 3 Muan;

the feet stand at an angle of about 90 degrees. The other costume accessories—collar, pendants, wristlets, anklets and sandals—are executed with great feeling and delicacy, and it may be fairly claimed that this monument is one of the finest examples of Maya plastic art, which has survived the vicissitudes of time.

The sequence of the hotun-markers at Piedras Negras, the monuments erected at the ends of successive 1800-day periods, is the most complete in the Maya area. At no other city was the custom of celebrating the ends of the successive hotuns by the erection of sculptured monuments so rigidly followed; at no other city is the monumental series so regular and uninterrupted over such a long period of time. Indeed, the results of Dr. Morley's investigations indicate that for a period of more than two centuries, *i. e.*, from 9.8.15.0.0 to 9.19.0.0.0 (349 to 531 A.D.) no single hotun-ending was permitted to pass without the erection of a corresponding sculptured monument.

Report of Harry E. D. Pollock on the Cobá Expedition

On February 21, Mr. Pollock left Chichen Itzá for Valladolid and proceeded eastward from there to Cobá. The object of the expedition was the examination and photographing of two newly discovered stelæ. These stelæ were found, and numbered 13 and 14 in accordance with the system of enumeration previously established at this site.

Stela 13 stands about 200 yards east of the southeast end of Lake Cobá and about 25 yards north of the main trail between Cobá and Macanxoc. Situated at the foot of a large mound, it faces south. The stela was apparently enclosed by a low wall about 10 feet square with low antæ projecting forward on either side of the stela proper. The outline of the enclosure is marked by a single course of stones at ground level, while within the square there is no fallen material other than from the antæ and rear wall which stand approximately 2 and 4 feet high, respectively. This would indicate that the enclosure may have been merely outlined at floor level, while it is quite certain that there was no roof.

The stela is in a bad state of preservation. Near the left edge a raised panel runs from top to bottom and carries the faintly visible outlines of incised hieroglyphs. At the lower right, a leg shown in profile is clearly discernible from mid-thigh to heel, which, in conjunction with faint traces of a waist and shoulder, suggests a standing figure facing to the left. Two broken parts of the stela were found and replaced, but a portion of the topmost glyph is still missing. The few glyphs are worn beyond all hope of decipherment. The monument measures 9 to 10 inches in thickness, 35 inches in width and 68 inches from the highest point to the bottom of the sculpture; the bottom six inches of the shaft are unsculptured.

In the process of preparing the stela to be photographed, it was discovered that it was set about 18 inches into the floor of the enclosure, and that 12 inches of sculpture were thus hidden. The low height of the monument and the existence of only 6 inches of unsculptured stone at the base point to the possibility that several feet of the lower end may have been broken off and the stone reworked to its present condition. Keeping in

mind the early dates, but rather late architectural types, known to exist at Cobá, these facts can not help but suggest that the stela was set up in its present position by a later people than the actual sculptors, perhaps as a venerable object rather than a contemporaneous record.

Stela 14 is situated about 200 yards south of the main trail and slightly west of due south from Stela 13. This places it on the isthmus between Lakes Cobá and Macanxoc. It is at the foot of a large mound running north and south, but itself faces southwest. In general, the local situation is similar to Stela 13, with antæ on either side of the monument.

This stela is in a more broken condition than the former, and the existence of hieroglyphs highly uncertain. In the lower left corner a small kneeling figure faces to the right, while in the center is faintly traceable the outline of the main figures with feet at an angle of 180 degrees and standing on what was probably the representation of a captive. In the lower right corner is another small figure that may or may not be in a supplicatory attitude. Between 25 and 30 broken pieces of this stela were replaced, and a large block of 3 parts, that pretty surely formed the upper right corner of the monument, was fitted together, but not replaced, because of the badly weathered edge of the standing section. The measurements are: thickness, 14 inches at the base, tapering upward; width, 55 inches; height, 62 inches from the highest point to the bottom of the relief; at least 18 inches below this is unsculptured.

As in the case of Stela 13, this stela was set into a floor, but all sculpture ceased at the floor level with a carved border line coinciding with plaster marks from the floor. Beneath the floor a fragment of well-sculptured stone, which did not belong to the stela, was found, but no other fragments came to light during the digging.

Time was so limited as to prevent any considerable exploration of the site. In a reconnaissance of two hours along the isthmus between Lakes Cobá and Macanxoc, however, several interesting architectural features were noticed, and an additional stela in completely ruinous condition was discovered. The site strongly gives the impression that more stelæ are to be found here, and it is felt that this city, which apparently possesses both Old and New Empire connections would well repay more systematic examination.

*Report of S. G. Morley on the General Status of Middle American
Archæological Research*

The moment is perhaps not inopportune to review briefly the general status of Middle American archæological research, and to indicate promising lines for early investigation.

The Institution has maintained for the past six years two principal centers of study in the Maya area—one at the Old Empire site of Uaxactun, in northern Guatemala, the other at the New Empire site of Chichen Itzá, in northeastern Yucatan, Mexico. Since the former is the oldest Maya city yet known, on the basis of the dated remains, and since Chichen Itzá was easily the most important city of the New Empire, and especially, since the excavations of the past six years have yielded results of great, not to say fundamental scientific importance at each, it appears advisable that investigations should be continued at these two centers.

The Government of Mexico, in addition to very considerable excavation projects just north of the Maya area (*i. e.* in central Mexico), and extensive explorations in the extreme southern part of the Republic, has carried on excavation and repair work at both Chichen Itzá and Uxmal in the northern Maya region.

The British Museum and the Field Museum of Natural History have excavated at various sites in western and southern British Honduras during the past three years—Lubaantun, Pusilhá, Hatzcap Ceel, Cahal Pichik, et cetera. The foregoing about exhaust the list of major excavation projects in the Maya field during the past six years.

During this same period there have been several expeditions, more exploratory in nature, which have visited the region, for different purposes, in behalf of other scientific institutions.

Tulane University has had two expeditions in the field, in 1927 and again in 1928, which visited the little-known southwestern part of the area, bringing back a large amount of new material, ethnological, linguistic, geographical, climatological, as well as archæological, especially from the highlands of Guatemala and southern Mexico.

The Field Museum of Natural History, in addition to its archæological investigations, has carried on ethnological studies, not only at various points in British Honduras, but also in the highlands of Guatemala; considerable vestiges of the ancient culture were found, myths, traditions, prayers, etc., which indicate that further work along these lines would yield important results.

The Peabody Museum of Harvard University has had expeditions in southern Mexico (Vera Cruz coast plain), Guatemala (highlands), and Honduras (Ulloa Valley) which have shed light upon these outlying, but strategically important, and, certainly culturally, related areas.

The Museum of the American Indian, Heye Foundation, has sent several expeditions to Guatemala, which have brought back valuable archæological and ethnological collections. This institution has laid special emphasis on the region south of the Maya field, especially Costa Rica, from which it probably has the largest ceramic collection in the world.

The American Museum of Natural History has confined its investigations more particularly to the highlands of central Mexico, where much progress has been made in classifying the complex but fundamentally important ceramic types of that region.

Finally, the Government of Guatemala, through the quasi-governmental Sociedad de Geografía é Historia has published a series of illustrated pamphlets on the archæological sites of the Republic, written in a popular vein, for the public schools, which has aroused widespread interest in the archæology of the country.

In addition to the foregoing activities of governmental and institutional agencies, Middle American archæological research has profited during the past six years by the investigations of several independent students. The fundamental studies of Dr. John E. Teeple on the Maya hieroglyphic writing merit special mention in this group. He has proved conclusively that Glyphs D and E of the Supplementary Series indicate in each case the age of the moon—number of days since new moon—on the date of the corre-

sponding Initial Series. In order to bring Dr. Teeple's work into closer relation with that of Dr. Morley, in the same field, the former has recently been appointed a Research Associate of the Institution.

The translations of Post-Conquest Maya manuscripts by Ralph Roys and those of Nahuatl manuscripts of the same period by B. L. Whorf are outstanding contributions to the study of Early American History.

During the past six years more than half a hundred investigators in archaeology, ethnology, physical anthropology, linguistics and history, representing a dozen different scientific agencies, governmental as well as private, have carried on studies in the Maya field, and a very considerable amount of information and material has been accumulated.

Expeditions involving enormous personal effort, prodigious hardship and costing, in the aggregate, hundreds of thousands of dollars have been carried through to brilliant conclusions. Many gaps in the body of existing knowledge have been filled; many blind spots in the picture of ancient Maya times have been painted in. The ground, it would seem, has been sufficiently covered for a restatement, a closer definition of the major problems of Middle American archaeological research, and the way cleared for a general attack.

It appears to the writer that the most pressing need of the moment is the organization of an informal Committee on Mayan Research, composed of members from the different institutions actively engaged in carrying on investigations in this field.

Some of the duties of such a committee would appear to be: (1) a careful re-examination of the results of previous investigations, and, in the light of these data, a restatement of the major research problems presented; (2) the organization of future investigations in such a way as to avoid duplication of effort; (3) the allocation of research problems and areas of exploration to the institutions and individuals best equipped to handle them, so that the maximum efficiency in research may be secured and, at the same time, concerted and correlated attacks made at the most strategic points; (4) finally, the establishment of a system of interchange of results, even of personnel in special cases, so that each problem may be served by the specialist best fitted to cope with it, and all institutions and individuals have the immediate advantage of the latest results of all investigations.

Such a condition as the foregoing is not a scientific Utopia impossible of achievement; rather, it would be the almost certain resultant of the formation of such a committee. Closer cooperation, direction of research, freer interchange of material and personnel would inevitably result in swifter and more effective solution of the problems presented, and a clearer picture of the ancient Mayan contribution to the development of mankind—the ultimate goal.

The specific problems suggested are some of those which the writer believes should receive priority of attention; they do not include, however, any outside the field of anthropology, important as are some of the allied problems in geology, climatology, biology, epidemiology, etc.

I. GENERAL PROJECTS

1. A survey of the Maya linguistic stock, especially along philological lines. This is recommended particularly as offering a proven means of approach for establishing the sequence in the separation of the various dialectic groups from the parent stock, and the reconstruction of the parent language.
2. A survey of Maya architecture. The frequent association of dated monuments with architectural remains, to say nothing of dated lintels, steps, jambs, cornices, wall-panels, etc., gives support to the belief that an extensive comparative study of all known Maya buildings would establish their chronological sequence, and would permit the relative dating of otherwise undateable buildings by means of stylistic criteria—such as type of ground-plan, façade-decoration, roof-ornamentation, etc.
3. A survey of Maya ceramics. The enormous bulk of Maya ceramic material, the complexity of wares, and multiplicity of shapes and designs, its occasional association with definitely dated monuments, and its very general occurrence at dated sites, render it extremely probable, if not indeed certain, that an extensive comparative study would establish the definite chronologic sequence of the various wares found, as well as their foci of distribution, and time relations with extra-Maya ceramic types.
4. The compilation of a Maya hieroglyphic dictionary. It is now possible to decipher the meanings of about one-third of the individual glyphs, and the publication of all known examples of certain signs will soon be feasible.
5. A translation and publication of post-Conquest Mayan and Nahuatl manuscripts. There exists a not inconsiderable body of unpublished and untranslated manuscript material, written in the Maya and Nahuatl languages with the characters of the Spanish script. As these manuscripts constitute practically the only documentary source for the ancient history of Middle America, their complete translation and publication has become a pressing need. Fortunately, in spite of the highly specialized character of this work, there are a few students sufficiently equipped to undertake it.

II. SPECIFIC EXPLORATION PROJECTS

6. The exploration of southern Yucatan and northern Guatemala. This is one of the least explored areas in the Maya field, and is, at the same time, scientifically, the most important, since in this region are located the transitional sites between the Old and New Empires. Expeditions from the Peabody Museum of Harvard University have penetrated the northern part of this region, and expeditions from the Carnegie Institution have worked in from the south. There still remains, however, a large intermediate section which has never adequately been explored, and which should contain sites of the Transitional or Colonization Period, 450 to 690 A. D. *circa*.
7. The exploration of the region lying west of the Usumacinta River, more especially the southern part between the upper reaches of the Usumacinta and Chiapas Rivers, comprising the entire Lacantun Valley and the great forests to the north, sometimes called "El Desierto." This is the eastern half of the State of Chiapas

in Mexico. Expeditions from the Ministry of Agriculture of the Mexican Government and from Tulane University have partially explored this region, but there are almost certainly unknown sites still hidden in these vast, practically trackless forests.

8. The exploration of the Territory of Quintana Roo, Mexico. The expeditions of the Carnegie Institution to the east coast of the Yucatan Peninsula, and more recently to the Old Empire site of Macanxoc-Cobá, in northern Quintana Roo, have developed the fact that this region was occupied as early as the Early Period of the Old Empire. A network of stone causeways traverse the section, and it is confidently anticipated that further exploration will bring to light other dated sites.

III. SPECIFIC EXCAVATION PROJECTS

9. The excavation of some site in the southern Vera Cruz coast plain. This region is the "no man's land" between the Maya and Nahuatl cultures, a meeting ground which has been strongly influenced by each. From this region comes the famous Tuxtla Statuette, the earliest dated object in the Maya hieroglyphic writing, 98 B. C. *circa*. Recent expeditions from the Peabody Museum of Harvard University have discovered highly important transitional material here.
10. The excavation of some western Old Empire site, preferably on the Usumacinta River. The east, north and south sections of the Old Empire have had considerable excavation, going back more than 40 years, but the west has been entirely neglected. An intensive excavation project in the Usumacinta Valley, where Maya art attained its most brilliant development, is greatly needed.
11. The excavation of some western New Empire site, preferably in the State of Campeche, Mexico. The archæological remains of the eastern half of the Yucatan Peninsula are much better known than those of the western half, and yet, the early explorations of Teobert Maler in this region and the more recent expeditions of the Ministry of Public Education of the Mexican Government and of the Carnegie Institution clearly indicate its archæological importance. The selection of a type site for intensive study would shed much light on the archæology of this little known region, and at the same time supplement excavations now being carried on elsewhere in the Yucatan Peninsula.
12. The excavation of some site in the highlands of Guatemala. In ancient times the Pacific coast plain of Guatemala was a main thoroughfare for north and south migrations. Along this great natural highway, the only feasible land route between North and South America, there must have been constant shifts of population in very early times. Some of these groups penetrated the highlands of Guatemala and occupied different parts of the high central valleys. Here, perhaps, next to Uaxactun, is the most likely place to find the "meeting ground" of the Archaic and Maya cultures. The establishment of the relationship between these two great composite cultural groups would constitute one of the most fundamental contributions that could be made to the field of Middle American archæology.

BIOLOGY

Bailey, I. W., Bussey Institution, Forest Hills, Boston, Massachusetts. *Study of structure and function of the cambium, or embryonic tissue of higher plants.*

An extension of the scope of our investigation upon the cambium and its derivative tissues has necessitated the development of special techniques: (1) methods for examining living tissue cells, and (2) essential modifications of the usual methods of fixing and of embedding plant tissue. The grant from the Carnegie Institution has been used to enable Dr. Conway Zirkle to attack the latter of these tasks. Dr. Zirkle has solved his problem, and we are now able by a concatenated effort not only to compare the results secured by two entirely different techniques but to study the effects of specific fixatives and reagents upon the visible structures of the living cell.

In addition to developing this technique for the embedding and sectioning of hard plant tissues, Dr. Zirkle has made a study of cell division in the cambium of various Coniferæ, fixed by fluids designed to preserve particular constituents of the cell and to destroy others. The large nuclei of the cambial initials provided especially favorable material for the study of the nucleolar material, separated chemically from the chromatin. An account of both nucleolar material and of chromatin during karyokinesis is being prepared for publication.

Furthermore, by comparing the form of the vacuome in living and fixed cells, Dr. Zirkle has devised special fixatives which so preserve the cytoplasm that the shape, size and number of the vacuoles in both primary and secondary meristems may be determined. A detailed account of this work has been prepared for publication.

Castle, W. E., Harvard University, Cambridge, Massachusetts. *Continuation of experimental studies of heredity in small mammals.* (For previous reports see Year Books Nos. 3-27.)

Studies have been made during the past year of problems of inheritance in rabbits, mice and rats.

In rabbits the study of size inheritance in relation to the inheritance of mendelian genes located in four different chromosome pairs has been brought to a conclusion, with wholly negative results, as forecast in the last report. No indication of linkage with size has been discovered in the case of four coat-character genes located in as many different chromosomes. The dominant genes which were introduced from the large-sized parent, when considered singly or as a group, are found no oftener in the larger than in the smaller descendants. A complete account of this investigation will soon be published in the *Journal of Experimental Zoology*.

The embryological studies on large-size and small-size rabbits made in cooperation with Dr. P. W. Gregory have yielded interesting results. We have been able to confirm the conclusion stated in my last report, that large size rabbits have a more rapid rate of embryonic growth without

more rapid differentiation. Consequently at corresponding stages of development the embryo of a large race is greater in absolute size, contains a larger number of cells of the regular size and consequently a greater mass of tissue. Although eggs of large-race and small-race rabbits are at fertilization of exactly the same size, the cleavage rate and growth of the former is more rapid. At 48 hours after mating, the egg of the large-size rabbit is nearly a cell generation more advanced in cleavage, containing about 32 cells when the small-race egg contains 16. When the blastocyst stage is reached, the blastodermic vesicle of the large-race rabbit is decidedly larger and a larger embryo results. We have been able to trace back the difference in rate of development as far as the 4-cell stage, about 25 hours after fertilization. Doubtless it exists from the very beginning and is inherent in the fertilized egg. A paper embodying the results obtained last year is in publication in *The Journal of Morphology and Physiology*. A further investigation now in progress will be published later.

The study of the linkage relation of the new gene *rex* (or plush like) coat in rabbits has been completed with negative results, showing that *rex* lies in a previously undescribed linkage system. A paper on this investigation has been published in *The Journal of Heredity*; another is in press to appear in *Zeitschrift für induktive Abstammung und Vererbungslehre*.

Yellow fat, stated in my last report to depend upon a gene linked with albinism (as originally described by Pease), has been shown to cross over with a frequency of 7.4 ± 4.1 per cent in relation to the albino gene.

Investigations with mice have been continued by Dr. Keeler, Dr. Pincus and Mr. Snell. Snell has determined the linkage relation of short-ear to dilution to be a very close one, with a fraction of 1 per cent of crossing over observed. He has discovered a new linkage, between hairless and piebald, with about 6 per cent of crossing over in females and 3 per cent in males. These figures have a high probable error, as the number of observations is still small, but are interesting as supporting the difference in rate of crossing over in the two sexes as reported by Castle and Wachter for other characters in mice and rats. Snell has also discovered a race of dwarf mice which crop out as mendelian recessives in a particular strain. These animals are apparently sterile, but the heterozygous parents afford material for interesting studies of genetic linkage and physiology.

Dr. Keeler is continuing his studies of mice having rodless retinas with special reference to linkage and other questions incidental to his work in ophthalmology at the Harvard Medical School.

Dr. Pincus has described the spontaneous appearance in one of his inbred strains of mice of the mutation known as black-and-tan, which has been shown by Dunn to be an agouti allelomorph. Its origin beyond question was independent of the mutation described by Dunn, which puts black-and-tan in the category of a recurrent mutation.

Dr. M. R. Irwin, Research Fellow in Biology, has conducted investigations on the inheritance in rats of susceptibility to certain pathogenic organisms, which he will continue another year at the Rockefeller Institute in New York.

In planning work for the coming year major emphasis will be placed on the rabbit investigations, new equipment for which is being installed.

Crampton, Henry E., Barnard College, Columbia University, New York, N. Y. *Continuation of studies concerning variation of the genus Partula with relation to geographical distribution.* (For previous reports see Year Books Nos. 7-10, 22-23, 26.)

The Carnegie Corporation of New York appropriated funds in the spring of 1928 to cover expenses of an additional field trip by Dr. Crampton. With his son, Henry E. Crampton jr., and Richard E. Goetze, a volunteer assistant, Dr. Crampton left New York for the Caroline Islands, via Japan, on June 1, 1928. Soon after reaching the islands he became very ill, and work in the field had to be relinquished. Dr. Crampton, however, had visited the Bonin Islands, the Mariana Islands—for a second time, Yap, and the Pelew Islands. General collections of land-snails were made in all of these groups, and in Angaur as well; although only in Saipan and Tinian of the Mariana Groups were *Partulæ* obtained.

Dr. Crampton proceeded to Manila to obtain adequate medical treatment, and during his three-months recuperation had many profitable conferences with men of science. Returning by way of China, a week was spent at Lingnan University of Canton, where he was able to assist the scientific men of that institution in various ways, and to address the students. Then he went to Honolulu, to spend four weeks at the Bishop Museum, whose facilities had been generously and fully put at his disposal by Director Gregory and Curator C. Montague Cooke jr. The collectors of the Bishop Museum have obtained *Partulæ* from several groups of Pacific Islands, and these were made available to him.

During the summer of 1929, Dr. Crampton returned to the Bishop Museum in Honolulu and continued his study of collections of *Partulæ*, with the result that a volume on the species of the Samoan Islands should be ready for publication in another year. In addition, material from the Fiji Islands and parts of Melanesia were studied, and next year further study will be given to species of the Marquesas Islands when more material will have arrived from that group. Furthermore, Dr. Crampton brought back with him live experimental material which is doing well under limited greenhouse facilities. All of the work accomplished and in progress coordinates well with that of Dr. Cooke of the Bishop Museum.

Mann, Albert, Washington, District of Columbia. *Continuation of investigations and preparation for publication of results of work on Diatomaceæ.* (For previous report see Year Books Nos. 18-27.)

Work this year has been somewhat larger in quantity and more varied in character than in any previous year; although in this small and technical field there is necessarily much similarity between one year and the next.

The third year of collecting at the Carnegie laboratory at Dry Tortugas was very successful. In addition to this, a set of unglazed tiles were anchored in the vicinity of the laboratory and after ten days the diatoms they had collected were scraped off, bottled and labeled. The tiles were then reset, left for two months and the process repeated. By this means we

expect to determine the true living diatom flora for the same season in successive years, a very useful biological fact that can not be obtained by the usual methods of dredging, as living and dead diatoms of several years' growth are inevitably mixed up in such collections.

Bearing on the Tortugas flora, about forty samples were secured last summer in and around Tampa Bay and others at Key West, so as to discover what differences in diatom floras may exist at these two Gulf of Mexico localities and at Tortugas.

Six weeks of work at Woods Hole, Massachusetts, were given to collecting during July and August, and further work was done on the attempt to enrich barren stretches of the shore by transferring living microorganisms, including diatoms, from nearby fertile areas. The practical bearing of this is its possible effect on an increase in the general shore fertility to supply larger food supply areas for fish and mollusk life.

At the request of the Bureau of Chemistry, ten samples of oysters from Chesapeake Bay were examined for the food diatoms they contained.

During the summer an interview was held with a representative of the Johns-Manville Company, at which the commercially important diatom beds in this country and in Europe were compared as to quality, quantity and availability of their diatom earths. The Johns-Manville Company subsequently secured control of the largest known diatom deposit—that of the Celite Company at Lompoc, California.

At the request of the New York Microscopical Society 100 choice diatom negatives were turned over to a local photographer and photographs made for the use of the Society.

Three days were given to Mr. Frederick Adams of Mexico City and London in identifying diatoms collected by him along the Mexican coast on the Pacific side and at Yucatan.

An exhibit was prepared and maintained at the annual Carnegie Exhibition, illustrating methods of collecting diatom material, preparing it for study and making permanent microscope slides for future use.

One hundred and fifteen diatom specimens were identified for the Liverpool, England, Microscopical Society.

A sample of diatom incrustations on rock was studied for Mr. Copley Amory of Matameck, Canada.

Twenty-one samples of plankton diatoms from Monterey Bay, California, were received from Mr. H. B. Bigelow of Harvard University and prepared for study.

A report was made on some fresh-water diatom earth from Ireland, received from the Celite Company of Lompoc, California.

Several samples of diatom earth were received from Mr. Frank Hess of the Bureau of Mines and from Dr. N. H. Darton of the Geological Survey. One of the latter, from Hilltop, Arizona, proved to be strikingly unlike anything hitherto discovered.

Seven samples of dredged diatoms from Callao, Peru, and the vicinity of the Easter Islands were received from the *Carnegie*. Only a general examination has as yet been made, but they are of unusual richness in subtropical forms.

A large number of samples of Alpine diatoms from the mountains of British Columbia was received from Dr. W. R. Taylor of the University of Pennsylvania. They await examination.

Identifications and a report were made for Dr. Willis Rich of the Bureau of Fisheries of 8 collections of diatoms from Karluk Lake, Kodiak Island, Alaska.

A diatom manuscript was reviewed for the Scientific American; also one for Dr. G. Dallas Hanna of the California Academy of Sciences.

A diatom collecting outfit was assembled for the Gifford Pinchot expedition in the South Pacific.

Bottom diatom material from Saco Bay, Maine, was examined and a report made for Mr. D. E. Owen of that locality.

Seven diatom samples from hot springs in Yellowstone National Park were examined for Dr. E. T. Allen of the Geophysical Laboratory. They were taken from waters ranging from 75° to 93° C. and proved so unusual and so suggestive in connection with researches in geology and vulcanology of that region now being made by the Geophysical Laboratory that further collecting of diatom material there will be undertaken during the coming season.

A new process for blocking out the backgrounds of diatom and similar negatives has been worked out with sheets of red "Cellophane," replacing the general method of painting out the backgrounds. It has proved to be a much easier and more effective method; a descriptive report of the process will be published.

After some wearisome delays, caused chiefly by repeated additions of new material, an extensive report on the diatoms of the Shackleton South Pole Expedition and the Australasian Antarctic Expedition has been finished and the manuscript and photographs are ready for shipment to Sidney, Australia, for publication. Perhaps the most useful facts in these investigations will be the striking dissimilarity between the diatoms of the Arctic and the Antarctic, and especially the apparent subtropical character of many of the genera and species in the Antarctic described in this report.

Morgan, T. H., A. H. Sturtevant and C. B. Bridges, California Institute of Technology, Pasadena, California. *The constitution of the germinal material in relation to heredity*. (For previous reports see Year Books Nos. 15-27.)

For several years stocks have been in process of construction which can be used to make other stocks homozygous without long-continued selection. Crossing-over suppressors are used to hold the desired chromosome intact and a dominant mutant character to mark the chromosome carrying the crossing-over suppressors. The stocks used (see Year Books Nos. 26 and 27) are, for the X-chromosome, CIB and attached-X yellow; for chromosome II, Curly speck, and for Chromosome III, Df 2C ca. During the past year these stocks have been combined in such a way as to enable them to be used simultaneously in the production of new stocks homozygous for any given X, II and III chromosome.

The most useful stocks to possess in an entirely homozygous condition are the basic "wild" stocks, which enter into many experiments, and contribute chromosome material to most stocks that are kept for future experiments. The wild stocks that have been most used are the California, which dates back to 1912; the Swedish, to 1922; the Florida, to 1923; and the Oregon, to 1925.

From the California wild, two homozygous strains, identical in appearance, were secured, consisting of flies which, in comparison with average wild strains, were relatively robust. The wings were a little short and the eyes noticeably large. The productivity was high.

From the Swedish stock three strains were secured. Two of these were identical in appearance and consisted of flies not markedly departing from the usual characteristics of wild *D. melanogaster*. The other strain showed a mutant character, *viz*, rotated genitalia of the male. The external genitalia of the normal male may be described as rotated clockwise through 360° as compared with the position of the genitalia of the female. This rotation is not apparent externally but is evidenced internally by a spiral counterclockwise looping of the sperm duct about the intestine. In the males of this mutant strain the above rotation is partly or wholly undone by counter-rotation of the external genitalia. They now appear in an abnormal sidewise or upside-down position. The amount of visible reverse rotation of the external genitalia may be as great as 270° , but is usually 180° , 90° , or some slighter amount. Usually 30 per cent or more of the homozygous males fail to show any rotation. These normal-appearing males have so far been sterile, though the tests have not been extensive. The amount of rotation and the proportion of males in which rotation can be observed is highly variable.

A progressive undoing of the normal rotation of the genitalia and ducts is characteristic of the triploid intersexes as they become less male-like and more female-like in characteristics. This suggests that the mutant just described may have something of the nature of an intersex. It might be a mutation in one of the sex-determining genes and consequently throw the balance in the male in a female direction. The homozygous females of this race would then be slight superfemales. They appear approximately normal.

The locus of the "rotated" gene is in the third chromosome, very close to the locus of Dichæte. On the basis of preliminary determinations the locus is 1.3 units to the right of Dichæte or at 41.7 on the standard map.

From the Florida race four homozygous strains were isolated. All showed one and the same mutant character, namely, "terraced eye." The terraced eye is larger than normal and divides more or less completely into two parts, resembling kidney. At the level of the notch there may be a protrusion of the tissue or else extra bristles. The terraced strain was fertile and productive. The character is recessive, located in the second chromosome, probably in the neighborhood of 35 on the standard map. Casual examination of the original Florida stock did not show terraced present, but it is believed that mass cultures have an unfavorable effect upon the development of the character, which fluctuates widely.

From the Oregon race three strains were isolated, of which one seemed entirely normal and showed the slight individual characteristics of the Oregon stock, namely somewhat elongated body and slender wings and slightly darker general color. The second strain was identical with this at first, but, after some generations, one of two subcultures was found to show a tannish body color in rather high frequency while the other subculture was free from it. The normal substrain subsequently showed no tannish. The tannish character is a recessive in chromosome III, with a locus somewhere in the left limb. The tannish flies were small and their productivity poor. Probably tannish arose during the experiment, as it was not seen until five generations had elapsed after isolation of the strain, and then was part only of one subculture.

The third strain of the Oregon race showed a peculiar mutant, namely, female-sterility. Homozygous males were normal and fertile. Homozygous females appear normal, but the ovaries remain rudimentary. The race is continued by balancing against the fertile Cy sp combination, the Curly females carrying the female-sterile condition in heterozygous form. Homozygous males of the strain were crossed to Bristle Lobe² females and the F₁ Bl L² females back-crossed to homozygous males. The BC females produced were isolated and held for several days. The separation then became simple, since the normal females produced many eggs which could be seen through the distended abdominal wall. The locus of the female-sterile gene is far to the left in chromosome II.

A relatively slight amount of inbreeding should render chromosome IV homozygous, since there is little or perhaps no crossing-over in it.

Of the homozygous strains secured, those which showed no mutant characters were therefore two of Californian, two of Swedish, and two of Oregon ancestry. Of these, the Californian stocks represent the oldest material and our stocks probably have it infused into them to the greatest extent.

Three "special" mosaic individuals have been reported (Year Book No. 25) that were interpreted as composed of normal (2N) and of haploid (N) tissue. These mosaics occurred among the progeny of Minute-n females. The regular progeny of Minute-n mothers shows from 5 to 20 per cent of "piebald" mosaics, consisting of male tissue in the Mn daughters. The spots of male tissue (not haploid) represent an elimination of the maternal Mn-bearing X-chromosome only. This elimination occurs in embryonic stages, but at a relatively later stage than is the case with gynandromorphs, since the piebald spots are usually smaller, and several independent ones may occasionally be present in the same female. The male spots carry only the paternal X, and show whatever sex-linked characters the father carried, but do not show autosomal recessives that he carried.

The three special (2N and N) mosaics differed in that relatively large sections of the body were involved, and the body size, bristle size, facet size and other features differed sharply from the situation in the regular piebalds, and agreed with an interpretation of these as haploid tissue. Presumably not simply the maternal X was eliminated, but all the maternal chromosomes.

The important feature of these special mosaics lies in their relation to the theory of genic balance, for according to this conception haploid *Drosophila* should be female and not male, although all directly known haploid insects are male. In two of the three cases there were present features diagnostic of femaleness; in the other, the part of the body included in the mosaic was not such as to furnish evidence on this point. But two positive cases were considered rather insufficient evidence in view of the high interest of the relation. Accordingly several efforts have been made to secure further haploid mosaics.

The experiments were designed to give better evidence on two points—first, as to the haploid nature of the tissue and, second, as to the sex of the tissue. The haploid nature could be demonstrated by the presence in the tissue of recessive characters carried in the autosomes of the male, viz, in the second and in the third chromosomes. The sex could be diagnosed better by the help of the sex-limited character eosin eye, which is darker in the female than in the male. Check characters were introduced by way of the Mn females. Stock Mn/+ Cy/Bl Sb/H females were mated with w^e sn^s , b sp, h males. Thus, the Mn mothers carried four distinct dominant characteristics, two of which, Bristle and Stubble, could be detected on all areas of the body where bristles are present, while Hairless could be detected nearly as well. Any diploid Mn fly or portion of fly would show two of these characters (Cy H, Cy Sb, Bl H or Bl Sb). Any haploid tissue would not show these dominant characters, but would show the normal wild-type allelomorphic characters introduced by the father. Furthermore, haploid tissue would show the autosomal recessives, black, speck and hairy, while piebald or diploid tissue would fail to show them. In a succession of experiments several thousands of Minute-n daughters were raised from the above cross, but no further haploid mosaics were found. As the three former specimens appeared with a frequency of about 1 in 5,000 Mn females, it may require much more labor to secure new examples.

The effects of high and of low temperatures, of X-rays and of cathode rays upon the Mn mothers have been tried in an effort to enhance the tendency to elimination, but no autosomal mosaics were found.

The haploid mosaics previously found had occurred in a strain that was producing a high proportion of piebald mosaics. The haploid parts were large, indicating relatively early elimination. The frequency and the size of the piebald areas might therefore be used as an index of conditions favorable to chromosome elimination. In the early experiments, using regular 10-day cultures, it had been noted that the percentage of piebalds was at its highest soon after the Mn offspring began to emerge. Studies have now been made to determine whether the subsequent decrease was dependent upon the increasing age of the mother, or on changing culture conditions.

Thirty-seven Mn females of the special dominant-bearing stock were mated to males of the multiple recessive stock, and transferred daily to fresh culture tubes. Twenty-six produced large or fairly large progenies.

The total Mn daughters produced by the 26 females showed: no spot, 1,942; one small, 158; one large, 10; two small, 5; small and large, 7; two

large, 1. The average number of spots per hundred flies was thus 9.1. A striking relation is that 9 of the 19 large spots found, or approximately half, occurred with another spot. This confirms the idea that the conditions favorable to more than one spot are also favorable to large spots. Piebalds have been recorded as possessing independent spots if the spots were on opposite sides of the mid-line, or in different segments of the same side.

There was very little effect that could be ascribed to the changing age of the mothers. The percentage remained nearly constant at 8 or 9 for the first 18 days, then for 5 days more showed a considerably higher plateau ($18\pm$), from which the value again fell for the last three days. The plateau and final low stretch were calculated from relatively few flies since only 6 females lived the full 26 days.

The percentage of spots in 21 of the 26 females fell within the range of 4 to 11 per cent; in 3 it was at 16, and in one at 40. These differences seemed to hold throughout the life of the mothers, some of which might therefore be described as high-producers of piebalds.

The Mn daughters from the high-producing (40 per cent) female were used for a second large experiment. The transfers were made daily as before. Of the 38 females, 25 produced fairly large Mn progenies. The totals were: no spot, 1438; one small, 167; one large, 25; two small, 20; one small, one large, 5; three small, 3; two small, one large, 1; four small, 1; six small, 1. The average number of spots for the whole experiment was 15.9, much higher than the 9.1 observed in the former experiment. Two progenies contained 26 per cent of spots. From one of these a stock is being continued for future work.

The effect of age was approximately the same as in the previous case, viz, a nearly uniform, but in this case rising, value ($16\pm$) during the first 17 days, followed by a plateau ($20\pm$) for 9 days, with a drop to a low ($12\pm$) for the remainder of the 34 days.

The above two tests of the age effect have shown that the higher proportion of piebalds observed at the beginning of the emergence periods of a 10-day culture is not due to differences in the age of the female. For the period during which eggs are normally laid (less than 10 days) was here found to be characterized by a practically uniform production of piebalds. The plateau observed, even if it represented a real age effect, came only after 17 days of egg-laying. Presumably, then, the culture conditions at the beginning and end of the normal egg-laying period are the determining factor in the decrease of the percentage of piebalds, either by killing off piebalds in abnormally high proportion, or by affecting the initial elimination process.

In the above experiment four not-Minute flies were found that were piebalds. Three of them showed each a single large bristle typically singed. The other showed a small irregular patch of eosin in the normal red eye.

In four separate progenies it was found that all of the not-Cy flies showed the same new mutant character. From the pedigree it is certain that this mutant was introduced from the Oregon wild stock, where it had not been noticed. This mutant is a dominant, which in heterozygous form makes a wider space between the posterior scutellar bristles, and makes the wings shorter and more rounded. The locus of "Wide" is in the second

chromosome, to the left of Star. In homozygous form it is nearly lethal, but occasionally emerges in a form practically identical with the mutant "dachoid" that was found and discarded early in the *Drosophila* work.

The 38 mothers of the foregoing age experiment had been heterozygous for Mn, and some also for eosin and singed, or for eosin or singed separately. It was noted that the crossing-over was abnormally high, and careful counts on crossing-over were made for all the progenies containing eosin and singed and for sample progenies containing eosin or singed. All seven progenies heterozygous for eosin and for singed showed the high values. A total of 2,675 flies gave a mean value of 35.3 for the eosin singed recombination, and of 42.7 for the singed Minute-n recombination. The standard expectations for these recombination percentages are 19.1 and 35.7 respectively. The increase was therefore mostly in the left-hand region of the X.

Since the data were collected from series of one-day cultures, the effect of the age of the mothers upon this heightened crossing-over could be followed. The amounts of recombination in both sections and in total, and the proportion of double crossing-over, or the coincidence, remained substantially constant during the course of the experiment. Further studies are being made on the inheritance and action of this enhancer of crossing-over.

That one mutation may produce effects on widely different characters of the fly has been apparent since the very early work on *Drosophila*. That allelomorphic genes may affect these different characteristics to different degrees, and one allelomorph fail entirely to show a character sharply apparent in another, was also known. Thus, over 20 cut-mutations have been observed, some of which show depressed antennæ, others not; some modified aristæ, others not; some are poorly viable, others normal in viability; etc. There are also several sets of allelomorphs in which one allelomorph is completely sterile, while another is normally fertile. For example, there are 3 scute allelomorphs, the standard original, a slight allelomorph (fewer bristles removed), and a dissimilar slight allelomorph that is female-sterile.

During the past year a case was studied in which two mutants, very dissimilar in appearance but similar in location, had been regarded as distinct genes closely linked. The mutant small-eye (58.5 in X) is characterized by an eye of about half the normal area, situated rather far back on the head. The mutant vibrissæ is characterized by a tuft of bristles, like a mustache, on each side of the face above the mouth parts and below the eyes. The locus of this mutant is near that of small-eye (slightly to the right of forked). A cross between small-eye and vibrissæ gives daughters that are completely wild-type. We received from Muller a mutant, produced by X-rays, which was called by him small-eye, but which was seen to have, besides the small eye, a tuft of bristles as in vibrissæ. Crosses of Muller's small-eye to the original small-eye gave daughters that were normal small-eye, without vibrissæ. Crosses between vibrissæ and Muller's small-eye gave daughters that showed the vibrissæ character but had normal eyes. This same type of interaction—only the commonly possessed characteristics showing in the compound between different allelomorphs—was shown by truncate allelomorphs (Mohr, Zeit. f. Abst. und Verbugn.).

50) and by cut allelomorphs. Recently Dubinin (Biol. Zentralbl. 49) has studied a series of scute allelomorphs, produced by X-rays, and has interpreted similar behavior as due to different but overlapping deficiencies. But this "loss" view of mutations is not necessitated, as we have pointed out many times. An alternative view is that each mutant type is due to a distinct change in the gene. But since the gene is presumably very large and diversified in its parts, many different mutant changes may be present simultaneously, often in different parts of the gene, as in different side chains, each producing its characteristic effect.

With the help of Madame Dobzhansky considerable work has been done in determining the locations of mutations that have arisen recently, or had not been accurately placed previously. Also, we continually receive from other workers mutants which arise in the course of their work. These we add to our stocks and make determinations of the loci, or experiments confirming the locations as given by the donors. From Demerec we have received two mutants, rugose-56 and rough-63, which we have found to be allelomorphic to Mohr's mutant uneven; and from Muller still a third allelomorph. Our data, some 5,000 flies, added to the data published by Mohr, places the mutant at about 2.4 to the left of forked. The mutant tiny-bristle-53, received from Demerec, lies about 3.7 to the left of Bar. Demerec's mutant rough-64 lies about 3.0 units to the left of crossveinless. The mutant curlex, received from King, lies about 0.1 to the right of crossveinless. The short-bristle mutant received from Stern lies about 0.15 to the right of yellow. The twisted-abdomen mutant received from Demerec gave no recombinations with yellow in about 1,600 flies. The second-chromosome recessive thick-tarsus, received from Spencer, lies 0.6 unit to right of Bristle. The recessive rolled-wing lies 0.4 unit to the right of Bristle. Bristle itself was received from King and has a locus 0.2 to the right of purple. The mutant bronze-eye, received from Spencer, is an allelomorph of our safranin, lying about 3 units to the left of curved, or very near Lobe.

Further study of the mosaics produced by *simulans* females heterozygous for claret (described in Year Book No. 27) has shown that the account there given requires modification in one respect. The new data indicate that usually (perhaps always) only one polar body is concerned, rather than all three as previously stated. Further statistics are required, and are being collected.

Several new cases of translocations have been studied in the laboratory by Professor Dobzhansky. In addition to his cases, already published in part (Biol. Zentralbl. 49; 408, Proc. Nat. Acad. Sci. 15; 633), a translocation has been studied, in which about 35 units from the left end of chromosome II has become attached to the middle of the left limb of chromosome III, near the locus of hairy. Professor Dobzhansky has made cytological preparations of females heterozygous for this translocation, and these are not distinguishable from preparations of normal females.

In last year's report (Year Book No. 27) certain data from experiments on injuring the eyes of *Drosophila* were given. The experiments have been repeated on a large scale and somewhat varied. Injured red-eyed females of the Oregon wild stock, bred to Florida wild males, produced 7,892 males from 67 pairs. No sex-linked mutant characters appeared in any of these

males. There were two other mutants, one a minute male and one a male with spread wings. There was also one gynandromorph. In another experiment the eyes of a female from a stock with the sex-linked characters echinus, cut^a, garnet², were burnt, and she was then bred to an uninjured male with the sex-linked characters yellow, crossveinless, vermilion, forked. The F₁ females were bred (in pairs) to "X-ple" males (scute, echinus, crossveinless, cut^a, vermilion, garnet², forked). If a lethal mutant were produced, a ratio of two females to one male would be expected and the missing class of males could be identified and the lethal proven to have arisen in the sex chromosomes of the P₁ injured female. No lethal ratios were found from 118 females. There was one ratio that was probably lethal, from an additional female, but the full count was not recorded. On the other hand two lethals appeared in the control from an uninjured female. Another set of experiments in which the eyes of males were burnt was as follows. Such a male was bred to a female from the CIB stock, which carries, besides the dominant Bar, a lethal factor, and a non-crossover factor. The F₁ heterozygous Bar daughters carried the lethal and the non-crossover factors in one X, while the other X came from the injured male. She was bred to Oregon wild males. If the X-chromosome that this F₁ female had received from the injured P₁ male had carried a lethal, she would have produced only daughters (no sons), because the hypothetical lethal would have killed half the sons, and the other lethal, from the P₁ mother, the other half. This test is essentially the one devised by Muller for quickly identifying lethal sex-ratios. In 473 F₂ pairs no lethal ratios appeared. In all therefore, 8,483 X-chromosomes were tested for visible sex-linked mutants or for lethals, and none was found. The results suffice to show, at least, that injuries to the eye do not produce offspring with defective eyes, or any other modification in eye-color or structure, nor does the injury cause an increase in the occurrence of lethal genes in the X-chromosome. This conclusion holds, obviously, only within the limits of the numbers obtained. It may at least be claimed that the results are more accurate and extensive than any other experiments of the sort so far recorded.

In a forthcoming Carnegie publication (No. 399) the results of a long-continued experiment on a low-female producing stock with attached X's are described. The experiments were made to discover the cause of the exceptional sex-ratios that occurred, in which more males than females appeared (low-female producers). In order to test further the conclusions there reached it was necessary to make certain critical tests on stocks that were derived from males that came from broken-apart X's of the low-female producing females. More than ten such stocks have been obtained, each from a different detached X. Nearly all of these have given low-female producing stocks. Tests have also been made of the X-chromosome of one of these stocks to determine the locus of the gene involved. It appears that the semi-lethal gene, that brings about the death of more of the females than of the males in the young stages, lies at the right end of the X-chromosome beyond the locus of carnation. Owing to the scarcity of genes at this extreme end of the X, the locus can not be established any more accurately without great labor.

Sumner, F. B., Scripps Institution of Oceanography, La Jolla, California.
Continuation of ecological and genetical studies with Peromyscus.
(For previous report see Year Book No. 27.)

Work was continued during the past year, as previously, under the joint auspices of the Carnegie Institution and the Scripps Institution. About 560 standard flat skins were prepared by E. L. Sumner jr., who likewise assisted me with statistical computations. The skins were partly those of mice which had been trapped in Florida and Alabama during the preceding year, partly those of their offspring. Color determinations and areal measurements were made of the former series, and the computations of these values and those derived from the measurement of other characters were completed.

The field situation described in the Year Book of the Institution for 1927-28 (pages 335-339) was subjected to as searching an analysis as seemed possible with the data at hand. The results were embodied in two papers in the Proceedings of the National Academy of Sciences, February and June 1929. The differences displayed by the various local collections were studied as minutely as possible, and graphs were constructed, showing the relations between pigmental and other characters and geographic position. As stated in the preceding Year Book, there was a pronounced gradient, from the coast inland, in respect to various measurable characters relating to pigmentation. In general, the degree of pigmentation increased from the coast inland. This gradient was far from uniform, however, having a gentle slope from the Gulf Coast to a point about 40 miles north, where a rapid change occurred within the space of a few miles. This "area of intergradation" was succeeded by another belt in which the change was again gradual.

Evidence was offered to show that whereas individual differences in pigmentation are partly genetic, the mean differences between these local races are wholly so. Various alternative interpretations of this curious distributional situation were offered and their relative merits considered. While these can not be discussed here at any length, it may be stated that the viewpoint finally accepted as most probable rested on the assumption that the races of the coastal zone owe their conspicuous depigmentation to the areas of intensely white sand which are exposed to view throughout a part of their range. Since this type of environment prevails in a high degree only in the immediate neighborhood of the Gulf Coast, it was believed probable that the coastal population had spread inland, after becoming adapted to its littoral habitat. The latter, owing perhaps to exceptionally abundant food or other favorable conditions, may be supposed to have engendered a high population pressure, leading to this overflow.

This excessive depigmentation of the race *albifrons* (and the even more extreme condition of the island race *leucocephalus*) must accordingly stand in some direct causal relation to the exceptional whiteness of the substratum throughout an important part of its habitat. After considerable study of the situation, I can offer in this case no conjecture more probable than the familiar one of concealing coloration, achieved through the differential survival of the paler variants. This conclusion is somewhat at

variance with the belief stated in the Year Book for 1927-28 (pages 338, 339).

The most striking feature of the distribution pattern herein considered—the relative abruptness of the transition between the two major races, in the absence of either an ecological barrier or of interracial sterility—remains unexplained, although several possible interpretations have been discussed.

A second field of activity, in addition to this analysis of the *polionotus-albifrons* situation, has been a continuation of the study of interracial hybrids, resulting from breeding experiments conducted during the years 1924-1927. The amount of routine measurement and computation which has been involved in these studies has necessarily been very great, but fortunately these are now nearing completion, and a report will probably be prepared within the next few months.

Lastly, the search for specific and subspecific differences in physiological activities, referred to in the Year Book for 1927-28, has been under way for some time. There are now in use (1) recording wheel cages, to which the animals have been found to adapt themselves readily; (2) special activity cages, mounted on tambours, and connected with pens which record the animals' movements upon a kymograph; (3) drinking fountains with which it is possible to determine their approximate daily water consumption.

While any mean racial differences in these respects—if they actually exist—have thus far been largely masked by the great individual variability within each race, many points of interest have thus far been revealed regarding the behavior of these animals. The extent of the nocturnal activity of some individuals is scarcely believable. These studies are being actively continued with the assistance of Mr. Llewellyn G. Ross.

Tennent, D. H., Bryn Mawr College, Bryn Mawr, Pennsylvania. *Microscopic investigation of the fixing and staining reactions of substances extracted from the eggs of Echinometra lucunter*. (For previous reports, see Year Books Nos. 8, 9, 11, 22, 26, 27.)

During the past year I have continued microscopical and biochemical studies of the eggs and ovaries of the sea-urchin *Echinometra lucunter*. In this work I have employed Dr. M. S. Gardiner and Dr. D. E. Smith as part-time assistants. Dr. Smith has furnished me with neutral fat, saturated fatty acids and unsaturated fatty acids, prepared from *Echinometra* material. These have been fixed and stained, compared with similarly prepared sections of the actual tissues, and with comparable preparations of commercial substances. The result has been the demonstration of the fact that prolonged osmication of unsaturated fatty acids, followed by extraction with turpentine, gives preparations that are identical in appearance with those of the Golgi substance in fixed tissues. Osmicated neutral fat and saturated fatty acid are less resistant to solution in turpentine.

At Tortugas, in July, I prepared a new lot of *Echinometra* material by the Champy-Kull and the Ludford-Mann-Kopsch processes. With the help of Dr. Gardiner the study of this material has now been completed and the illustrations drawn.

The complete report of the study of alcohol soluble substances in *Echinometra* ovaries is now in process of preparation and will be submitted by February 1, 1930.

CHEMISTRY .

Noyes, Arthur A., California Institute of Technology, Pasadena, California. *Researches upon (1) free energies and reduction-potentials; (2) structure of crystalline substances determined by X-rays; (3) rates of gaseous chemical reactions; (4) chemical reactions produced by molecules activated by radiation; (5) spectra of modified radiation scattered by molecules; (6) atomic and molecular structure: theoretical; (7) general physics.* (For previous reports see Year Books Nos. 2-27.)

Funds supplied by the Carnegie Corporation of New York to the Carnegie Institution of Washington for the support of fundamental studies in chemistry at the California Institute of Technology have enabled the following investigations to be carried out.

1. FREE ENERGIES AND REDUCTION-POTENTIALS

The investigations, initiated by Dr. C. H. Prescott jr., on the equilibrium of reactions at very high temperatures have been continued by Dr. W. B. Hincke and Mr. L. R. Brantley. The equilibrium pressure of carbon monoxide resulting from the reaction between titanium dioxide and carbon has been determined; and the nature of the solid phases produced is now being investigated. The pressure has been found to vary from 60 cm. at 1278° A to 153 cm. at 1420° A.

The previously described work on the electrode-potential of sulfurous acid solutions against inert electrodes has been completed by Dr. H. H. Steinour, in cooperation with Professor A. A. Noyes. It is shown that a fairly reproducible electrode-potential of -0.37 volt is established in the half-cell $\text{Pt}, \text{H}_2\text{SO}_3 + \text{H}^+(\text{at } 1 \text{ n.})$ at 25°, and that this results from the presence in the cell of a reduction-product (probably $\text{H}_2\text{S}_2\text{O}_4$) arising from the spontaneous decomposition of the sulfurous acid. The existence of this potential, considered in connection with the known potential (-0.14 volt) of the $\text{H}_2\text{SO}_3\text{—H}_2\text{SO}_4$ electrode, enables the chemical behavior of sulfurous acid both as an oxidizing and as a reducing agent to be predicted.

The investigation of Mr. H. B. Wellman on the equilibrium of the reaction $\text{H}_2\text{PdCl}_4 + \text{Cl}_2 = \text{H}_2\text{PdCl}_6$ has been completed. The equilibrium value of the ratio $(\text{PdCl}_6^-)/(\text{PdCl}_4^-)(\text{Cl}_2)$ was found to be fairly constant, and to have a value of 3.710, which corresponds to a potential 0.071 volt when the pressure of chlorine gas is one atmosphere.

2. STRUCTURE OF CRYSTALLINE SUBSTANCES DETERMINED BY X-RAYS

With the aid of his rules governing the structures of ionic crystals Dr. Linus Pauling has deduced structures for the A-modification of the rare-earth sesquioxides La_2O_3 , Ce_2O_3 , Pr_2O_3 , and Nd_2O_3 which agree satisfactorily with the powder photographic data published by W. Zachariasen. Mr. J. H. Sturdivant, Mr. F. J. Ewing and Dr. Pauling have investigated the structures of the orthorhombic crystals tantalite-columbite, $\text{Fe}(\text{Ta}, \text{Nb})_2\text{O}_6$, diaspore, AlHO_2 , and spodumene, $\text{LiAlSi}_2\text{O}_6$. Mr. Sturdivant has designed

and constructed an X-ray apparatus for the purpose of preparing Laue photographs from crystals kept at liquid air temperatures; and intensity data from these photographs will be used for obtaining an accurate triple Fourier series representation of the electron distribution.

3. RATES OF GASEOUS CHEMICAL REACTIONS

Experimental and theoretical work on reaction velocities has been continued along the lines described in previous Year Books.

In association with Professor R. C. Tolman, Dr. Hermann C. Ramsperger and Dr. M. E. Nordberg have completed and published a series of measurements on the rate of decomposition of nitrogen pentoxide at pressures as low as 0.1 mm. and at three different temperatures. The rate was found to agree with the known high-pressure rate. This is a matter of considerable interest because of the wide discrepancy in the results which have previously been published on this reaction at low pressures. The reaction also has great theoretical interest, since it will be difficult to account for the rate of activation of molecules on the basis of collisional theories if the rate does not fall off at very low pressures. An attempt to go to still lower pressures is now in progress.

Dr. O. K. Rice, Dr. L. S. Kassel and Dr. H. C. Ramsperger, National Research Fellows in Chemistry, have all spent the whole or part of the past year at the Institute, working on problems of reaction velocity, and have published eleven papers relating directly or indirectly to this problem.

4. CHEMICAL REACTIONS PRODUCED BY MOLECULES ACTIVATED BY RADIATION

Mr. S. F. Ravitz, in association with Professor R. G. Dickinson, has investigated the effect of blue light in displacing the equilibrium $\text{Fe}(\text{CN})_6^{2-} + \text{I}^- = \text{Fe}(\text{CN})_6^- + \frac{1}{2} \text{I}_2$, and has compared the effort with that of the same light in displacing the equilibrium: $\text{Fe}^{+++} + \text{I}^- = \text{Fe}^{++} + \frac{1}{2} \text{I}_2$. Evidence has been obtained that the quantum yield is the same in both cases; although the first equilibrium is, on illumination, displaced to the right while the second is displaced to the left. This work is being continued.

Dr. A. O. Beckman has continued his study of the photochemical decomposition of the compounds produced of nitrogen and hydrogen by monochromatic ultra-violet radiation. The previously reported work on gaseous hydrogen azide (HN_3), which was done in association with Dr. R. G. Dickinson, has been completed and published. In association with Mr. R. R. Wenner the apparatus for the measurement of quantum yields has been greatly improved, and work has been started on the quantum-yield in the decomposition of gaseous hydrazine (N_2H_4).

5. SPECTRA OF MODIFIED RADIATION SCATTERED BY MOLECULES

The Raman effect given by aqueous solutions of a number of electrolytes, especially inorganic substances containing oxygenated anions, has been investigated by Professor R. G. Dickinson and Dr. R. T. Dillon. Considerable regularity in the frequency-shifts produced on scattering has been discovered.

A fast two-prism glass spectrograph arranged to operate at either of two different dispersions has been designed and constructed. With this instrument, very satisfactory Raman spectra from a number of substances have been obtained. The measurements on acetone, liquid ammonia and the crystal gypsum have already been offered for publication.

In cooperation with Dr. F. Rasetti, Fellow of the International Education Board, Raman spectra from the gaseous substances carbon dioxide, nitrous oxide, ammonia, methane and ethylene have been measured and published.

6. ATOMIC AND MOLECULAR STRUCTURE: THEORETICAL

In collaboration with Dr. B. Podolsky, Dr. Linus Pauling has obtained a general expression for the momentum eigenfunctions of a hydrogen-like atom. These functions give the probability that an electron in a hydrogen-like atom is a state characterized by the quantum numbers n , l , and m , having a given momentum vector relative to the nucleus.

A theoretical expression giving the electron affinity of a liquid or crystal in terms of its specific diamagnetic susceptibility has been derived, and applied in accounting for the long wave-length limits of the ultra-violet absorption regions of halide ions in aqueous solution and in alkali halide crystals and for the photosensitivity of the silver halides. It further leads to a theory of the dependence of the frequency of X-ray absorption edges on chemical constitution which is in quantitative agreement with the experimental data for crystals of the alkali halides.

Dr. Pauling has also given a discussion of the motion by hydrogen molecules in a crystal of hydrogen according to the quantum mechanics, which leads to the conclusion that the molecules are rotating even at the absolute zero. This requires a term $0.75 R \ln 3$ in the entropy of crystalline hydrogen which is substantiated by the experimental measurements of Giauque and Johnston. The concept that molecules in solids continue to rotate about axes with a small moment of inertia further accounts for the apparent two-fold axis of symmetry shown by the ammonia molecule in $\text{NiCl}_2 \cdot 6\text{NH}_3$, and explains other cases in which molecules in crystals simulate a higher point-group symmetry than they actually possess.

7. GENERAL PHYSICS

Professor R. C. Tolman has completed during the year, with the assistance of Mr. D. B. McRae, an experimental demonstration of the equivalence of a mechanically oscillated electrostatic charge to an ordinary alternating current of electricity, and has prepared the work for publication.

Professor Tolman has also published during the year an analysis of the astronomical implications of the de Sitter line element for the universe, and also a proof that the line elements of de Sitter, of Einstein, and of the special theory of relativity are the only cosmological line elements which would agree with those assumptions as to the distribution of matter in the universe which are the most natural ones.

PUBLICATIONS

During the past year nineteen articles have been published describing the researches outlined above or in last year's Year Book.

Richards, Theodore W., Harvard University, Cambridge, Massachusetts.

Continuation of exact investigation of atomic weights and other physicochemical properties of elements and of simple compounds. (For previous reports see Year Book Nos. 2-27.)

Dr. Lawrence P. Hall submits the following report with regard to publication of results of studies upon which Dr. Richards was engaged at the time of his death.

Since the preparation of the previous report, the researches there discussed have been carried to a point which permitted publication of the greater part of the data and results.

The study of the thermochemistry of aqueous solutions has been presented in several articles in the Journal of the American Chemical Society. In these publications will be found values for the heat capacities of solutions of various electrolytes, heats of dilution, heats of neutralization and the temperature coefficients of these values, as well as the development and use of the apparatus required for their determination.

Several papers on the compressibility of the elements have also been published in the Journal. In these publications are presented values for the cubic coefficient of compressibility of sodium, barium, strontium, beryllium, lead, thallium, indium and an indium zinc alloy. The purification and preparation of specimens of some of these elements for measurement is given.

Mr. Marcel Françon has concluded the study of the action of chloride solutions on mercurous chloride and the full account of this project has been published in the Journal of Physical Chemistry.

Another publication in the Journal of the American Chemical Society has been an account of the determination of the atomic weight of copper from the Lake Superior Region and from Chile.

There naturally remain unpublished a great many miscellaneous sets of data obtained in previous researches. In a few cases it is expected that some of this material will be published by the junior authors.

Sherman, H. C., Columbia University, New York, New York. *Chemical investigation of the amylases and related enzymes.* (For previous reports see Year Books Nos. 11-27.)

The work of the past year has brought to completion two important steps in the general project with which we are engaged.

The results of one of these, that dealing with the part played by neutral salts in the activation of pancreatic amylase, have been published during the year in a series of three papers in the Journal of the American Chemical Society, and appear to be of considerable interest both intrinsically and as pointing the way to further fundamental advances through similar investigations of other enzymes. Malt amylase (representative of those of green-plants) and the amylase of *Aspergillus oryzae* (representative of those of the fungi) are being investigated in this laboratory in an analogous manner, and some interesting similarities and differences among these three types of starch-splitting enzymes are being developed. A part of this work is being done without subsidy from the Institution, but all is so planned as

to contribute directly to the completion of the project in which the Institution is cooperating.

The second phase of the work accomplished is the completion of a comprehensive and critical experimental study of the purification and concentration of pancreatic amylase, undertaken both for the information that such an investigation in itself might now give regarding the enzyme and in the hope of obtaining larger yields of highly active material with which to continue the direct investigation of its chemical nature. The available possibilities of each of the two general methods of purification, that of fractional precipitation by alcohol and ether and that of adsorption, have been submitted to exhaustive experimental investigation. By the application of the newer knowledge of chemistry to the problem of obtaining optimal conditions in solution and more rapid and efficient precipitation, dialysis and adsorption, it has been possible to define more clearly and to render more satisfactory each of these procedures and to develop a new method of purification which combines the most effective features of both of those previously used. This new method yields larger quantities of purified and highly active material, and the product appears to be more consistently of a maximum activity than the products obtained by our earlier method of fractional precipitation and dialysis alone. This material, with an enzymic activity of 3,400 to 3,900 on the scale of Sherman, Kendall and Clarke, or capable of producing about 84,000 to 97,000 times its weight of maltose from 2 per cent starch in 30 minutes at 40° C., is obtained, like our previous preparations, in the form of a dry solid which can be accurately analyzed and studied much more thoroughly and conclusively than would otherwise be possible. It corresponds very closely in properties to the products obtained by our earlier method of fractional precipitation and dialysis, and like them appears to be typically protein in nature, having a nitrogen content between 15 and 16 per cent and showing the precipitation and color reactions of typical proteins. Like our earlier preparations it also possesses protein-splitting as well as starch-splitting activity, a point of considerable theoretical interest which should be investigated further and more quantitatively. It contains no detectable amount of carbohydrate.

This excellent agreement in the properties of the products obtained over a period of years by different methods, by different workers and from different starting material greatly strengthens our theory of the chemical nature of the enzyme, while at the same time the new method has advantages which seem to justify the anticipation that our further researches in this field can go forward more rapidly and at the same time more conclusively than has hitherto been possible.

It is not feasible to review adequately here the findings of theoretical and practical importance which have resulted from this extensive and rigorous study of the purification of the enzyme, but brief mention may be made of a few of the developments.

Our recent results confirm and extend our previous findings that the reaction of the solution has a marked influence upon the degree of success attainable at each of several different steps in the purification process and that this influence is especially important in the adsorption of the enzyme

by alumina gel and in its subsequent removal from this adsorbent. This relationship appears of special interest in connection with the amphoteric nature of the enzyme.

The finding previously reported that phosphate does not influence the activity of this enzyme and the subsequent finding that the adsorption of the enzyme by alumina gel is also not influenced, under the conditions of our experiments, by the presence of phosphate, have been very helpful in making it possible to use phosphate as a buffer to regulate the reaction of all solutions and thus to establish, maintain and reproduce the optimal conditions at each step in the process.

Alcohol adds very greatly to the effectiveness of the adsorption of this enzyme by alumina gel, and the optimal conditions for its use have therefore been established through extensive experimentation. This has involved quantitative determinations of the optimal relative and absolute concentrations of alcohol, alumina, and enzyme preparation, and of the hydrogen ion activities of the solutions.

Dialysis was found to be the source of greatest loss of active enzyme in both methods under consideration and the point at which there was the most difficulty in finding and in reproducing the best conditions. Collodion as purchased varies considerably and it is difficult to obtain uniform membranes with it. Much better results are obtained by the use of alcohol-ether solutions of a standard dry nitrocellulose preparation. Membranes obtained by the evaporation of such solutions under carefully controlled conditions upon a strictly level flat surface and used in a rotating dialyzer are very satisfactory. During the dialysis the room is kept cold, and the dialyzate is frequently replaced by cold 50 per cent alcohol which has been found to be more satisfactory than water with this enzyme. The employment of a large surface of membrane and the more efficient contact during rotation shortens greatly the time necessary for dialysis and reduces considerably the loss of active material. The volume of the enzyme solution is kept practically constant and with the form of apparatus here used the solution on either side of the membrane may easily be replaced in whole or in part without disturbing the other. This makes it now possible to carry forward, with reasonable assurance of success, certain direct studies of the products formed during enzyme dialysis, which we have long contemplated. There is considerable evidence that the inactivation of pancreatic amylase in aqueous solution is at least partly due to hydrolytic changes in the enzyme molecule. The loss of activity which occurs during dialysis as ordinarily carried out is due both to mechanical losses of active enzyme through the membrane and also to inactivation which is probably similar to that which takes place in ordinary solution but more drastic because of the removal of the products formed. The mechanical losses may now be controlled and the conditions thus become more favorable for further study of the products formed. We are planning to accompany and extend this further work upon dialysis by parallel studies of the products formed during ultrafiltration, a process which is now also being successfully applied to enzyme solutions.

Glycerol has been added to enzyme solutions by many previous workers because it was empirically found to result in more active extracts. Presumably, according to our hypothesis, it decreases the hydrolysis which inactivates the enzymes. The advantages of its presence have in the past, however, been more than counter-balanced (from the standpoint of study of the chemical nature of the enzyme) by the practical impossibility of its complete removal. Previously, dialysis has been depended upon to remove the glycerol. We find, however, that traces of glycerol remain in solution even after prolonged and careful dialysis and that its presence makes it difficult to obtain dry preparations and often makes misleading the final analyses of the product. For this reason we use glycerol in the early stages of purification but omit it from the solutions from which the final product is precipitated. It is entirely feasible to separate the enzyme from the glycerol during the adsorption of the enzyme from its alcohol-water-glycerol solution by alumina gel. In our method as finally developed, glycerol is not added to the solutions used to extract the enzyme from the alumina or to the subsequent solutions.

The possibility of the use of other steps to increase the efficiency of the new method has been carefully investigated. In general, further manipulation, such as the use of more than one adsorption and extraction as advocated by some European workers, of preliminary dialysis, and of reprecipitation and washing of the final precipitate, have been found to result in less active products.

The efficient collaboration of those who have shared in this work, whether as research assistants or as volunteers, is gratefully acknowledged.

Similar work with malt amylase is now in progress. As mentioned in previous reports, a broadening of this work is important to our understanding of the chemistry of life processes.

GENETICS

Babcock, E. B., University of California Agricultural Experiment Station, Berkeley, California. *Investigations in the genus Crepis*. (For previous reports see Year Books Nos. 25-27.)

The investigation of this large group of more or less closely related species has proceeded along the same general lines as were indicated in the last report. The progress in each of these phases is summarized below.

TAXONOMY

The problem of generic limits has received considerable attention and definite conclusions have been reached concerning most of the groups which are closely related to *Crepis*. These conclusions have been based on the available evidence from chromosome number and morphology along with other taxonomic criteria. Closely related groups which are to be excluded from *Crepis* are: *Hieracium* Sect. 33 of Zahn's monograph, *Crepidisperma* A. T.; *Ixeris* Cass., *sensu strictu*; *Crepidiastrum* Nakai; *Aetheorrhiza* Cass.; *Youngia* Cass., *sensu strictu*; and *Crepis* Sect. 5 of Hooker, *Glomeratae*. Groups previously recognized as genera which should probably be included under *Crepis* are: *Rodigia* Spr. and *Pterotheca* Cass. The limits of the genus are now outlined with a fair degree of definiteness, and this will facilitate all future investigations. About one-third of the species in the genus have been brought under cultivation. The information derived from the study of and experimentation on these living plants has aided so much in analyzing the difficult problems of phylogenetic relationship within the genus that further efforts should be made to collect living material of as many as possible of the remaining species. To do this will require several years. It has been decided, therefore, to postpone completion of the monograph of the genus which was originally proposed and, instead, to prepare a purely taxonomic revision of *Crepis* at as early a date as possible, including such new species as have not already been published. During the past year, ten new species from southern Asia have been published.

CHROMOSOMES AND PHYLOGENY

The number and morphology of the chromosomes in 67 species of *Crepis*, and three other species that were previously considered as *Crepis*, have been described by Dr. Hollingshead and studied by Babcock in relation to the phylogeny of the same species as indicated by external morphology and geographic distribution. The genus is divided into four subgenera, *Paleya*, *Barkhausia*, *Catonia* and *Eucrepis*. *Paleya* is the most primitive of these and contains four or five species, only one of which has been examined cytologically. There is close resemblance between its chromosomes and those of certain species of *Barkhausia* and they are also similar morphologically. It happens, however, that *Barkhausia* is also the most highly specialized of the four groups, and there are striking modifications in the chromosomes of the more specialized species. *Catonia* shows relationship to a different species of *Paleya* but some species of *Catonia* are so different from this species of *Paleya* that it is necessary to assume more than one

prototype. In *Eucrepis* the connection with *Paleya* is still less clear and it is even more heterogeneous than *Catonia*. Yet the species are obviously related. They fall into several distinct subgroups and the study of the chromosomes has been of great assistance in working out these groups.

The chromosome numbers found are: *Paleya*, 10; *Barkhausia*, 8, 10, 10-13, 16; *Catonia*, 8, 10, 12, 16; *Eucrepis*, 6, 8, 10, 12, 14, 15, 16, 22, 33, $40\pm$, 44, 55?, 88?.

The native American species of *Eucrepis* (excluding *C. nana* and *C. elegans*) have a common base number ($n = 11$) which is different from all other *Crepis*. As no closely related species has been discovered in the Old World it has been necessary to assume for the present that they originated by a method which has been experimentally demonstrated to be possible, viz, hybridization between two species, one with $n = 6$ and the other with $n = 5$ chromosomes (or one $n = 7$ and the other with $n = 4$ chromosomes) followed by a complete doubling of the chromosomes which would give 22 for the somatic number. There is considerable evidence to support this hypothesis. Other chromosome numbers in the series which may have arisen in similar fashion are 12 and 14. Such an origin would explain the absence of definite prototypes among existing species.

Considering the genus as a whole as to chromosome number, there still remains the lower portion of the series, viz, 6, 8, 10, to be explained. Evidence is being accumulated by the cytological investigations now under way which may furnish a satisfactory explanation.

CHROMOSOMAL VARIATIONS

An extensive study of triploidy in *Crepis capillaris* ($n = 3$) and other species has been completed by Dr. Navashin. Triploid individuals have been found in many populations of three species of *Crepis*. It was found that as much as 0.5 per cent of the total population in *C. tectorum* consists of triploids and tetraploids; while in *C. capillaris* a similar proportion of triploids was found, but no tetraploids. Such a high rate of occurrence can not fail to influence the biological relations of the species involved. The first and second generations obtained from the original triploid *capillaris* plant have been investigated cytologically, over 1,000 individuals having been examined. Of these, 64 per cent were diploids, 29 per cent triploids, and 7 per cent were single and double trisomics, triploid tetrasomics and higher grades of polyploidy. Of the six possible trisomic types in this species five have been found and studied. By crossing experiments the occurrence of viable triploid, tetraploid and possibly pentaploid and hexaploid eggs has been proved. Triploidy in *Crepis* may play a considerable part in the formation of new species through production of higher grades of polyploidy, which in turn make possible penetration of the species into new territory and there crossing with other species.

An analysis of the relation between quantity of chromatin present in nucleus and the size of meristematic (undifferentiated) cells has been investigated during the year by Dr. Navashin. It was found for 13 species of *Crepis* investigated that the volume of the cell was proportional to the amount of its chromatin. It was established that specific differences in amount of chromatin have the same primary consequences as intraspecific

variation in number of the homologous chromosome sets arising through polyploidy. This suggests that specific differences in amount of chromatin are associated with differences in quantity of homologous genes as in polyploid series. It is also shown that the proportions of cell divisions of primary meristem are confined to a series of simple fractions, which indicates that cell divisions and the resulting simplest cell patterns are controlled by some elementary physical process.

INTERSPECIFIC HYBRIDS

A contribution of considerable interest is the completion by Dr. Hollingshead of the analysis of a genetic factor, present in *Crepis tectorum*, which is lethal only in interspecific hybrids. The three other species, in hybrids of which this lethal is known to be effective, are *C. capillaris*, *C. bursifolia* and *C. leontodontoides*. This lethal gene probably played some part in the evolution of *C. tectorum*. Its existence is another addition to the demonstrated causes of interspecific incompatibility.

Meiotic phenomena, the behavior of the chromosomes in the reduction divisions, as found in pure species and the hybrids between them, have a certain bearing on taxonomic relationship. A study of meiosis in *Crepis aspera* and *C. bursifolia* and the hybrids, *aspera* \times *bursifolia*, *taraxacifolia* \times *tectorum*, and *aspera* \times *aculeata*, has been made by Dr. J. Clausen and Babcock. The five species involved have $n = 4$ chromosomes which are of similar size in meiosis. In *bursifolia* one chromosome pair which is shorter than the other three pairs can be recognized through all phases. The chromonema thread in the early zygotaphase shows chromomeres and parasyn-desis have been found. In the diplotaphase the chromonema coils up into a spiral filament which in diaphase appears to be doubled by splitting. In this phase chiasmata between the partners of the bivalent chromosomes are often seen. These chiasmata may be regarded as the results of interchange accomplished at an earlier stage, before the chromosomes have become shortened by the spiral coiling of the chromonemata. Extraction of the chiasmatic chromonemata would occur in the heterotypic anaphase. In *aspera* \times *bursifolia* the structure of the chromosomes can be recognized as similar to that of the parent species and chiasmata can be found between the partners of the bivalent chromosomes. In pollen mother cells, where 4 pairs of chromosomes are present, a pair consisting of two unequal partners is seen and the short *bursifolia* chromosome can be recognized in all phases.

The five species would be classified as follows taxonomically: Subgenus A, Sect. III, *bursifolia*, *taraxacifolia*; A, IV, *aspera*, *aculeata*; B, VI, *tectorum*. Data on the hybrids studied may be summarized as follows: *aspera* \times *aculeata*, meiotic irregularities rather few, percentage of "good" pollen 35-50, percentage seed set 30-40; *taraxacifolia* \times *tectorum*, meiotic irregularities very numerous, percentage "good" pollen 1-2, percentage seed set few or none; *aspera* \times *bursifolia*, meiotic irregularities very numerous, percentage "good" pollen 1+, percentage seed set 3-4. These data are in close agreement with the taxonomic relations of the parental species with the exception that, if their relationship is below a certain threshold value, these criteria can not be used for determining how remote two species are from one another.

The creation of new species through artificial interspecific hybridization has been shown to be a practical possibility by the work of Dr. Collins and others with the derivative forms secured from the hybrid, *C. setosa* \times *C. biennis*. Such a synthetic form is *Crepis artificialis* which has 12 pairs of chromosomes, consisting of 10 pairs from *biennis* and 2 pairs from *setosa*. Morphologically *artificialis* is an intermediate connecting link between the subgenera *Eucrepis* and *Barkhausia*. *C. artificialis* stands as an experimental demonstration of a mode of origin of species which differ from the parents and all other species both in external morphology and in chromosomes. New species can arise suddenly in this way and such species are not the result of gradual change by the successive accumulation of minute differences. It must not be inferred from this evidence, however, that this method is the most usual one concerned in the evolution of *Crepis*. From the evidence at present available, it appears that such origins have been the exception rather than the general rule in this genus. Other constant fertile forms of similar derivation are under investigation.

CREPIS LEONTODONTOIDES HYBRIDS

In her attack on the problem of phylogenetic relations of this species, Miss Avery has investigated hybrids between it and species belonging to three subgenera, viz, in *Barkhausia*, *C. marschalli*; in *Eucrepis*, *C. tectorum*, *C. capillaris* and *C. parviflora*; in *Catonia*, *C. aurea*. From study of the hybrids and their meiotic phenomena, it is concluded that *leontodontoides* is more closely related to *aurea* than to any of the other species and that these two species had a common ancestor with 10 chromosomes. It is probable that this ancestor was more like *Catonia* than *Eucrepis*, but that the evolution of *leontodontoides* involved the development of *Eucrepis* characteristics, possibly through hybridization. This investigation has demonstrated that "breeding behavior, chromosome number and morphology, and the behavior of the chromosomes in the reduction divisions of the F_1 hybrid indicate a closer relationship than do external morphological characters alone." Thus it provides a good illustration of the advantages derived from the synthetic method of combining the evidence from taxonomy, cytology and genetics in attacking difficult problems in phylogeny and evolution.

This report is based largely upon the papers which have been published, filed in the University of California Library, or sent to press during the year (see Bibliography).

The following persons have assisted in the work during the past year: Dr. J. Collins, assistant professor of genetics; Dr. M. Navashin of Moscow, Russia, associate in genetics; Mr. C. W. Haney, technical assistant; Dr. Lillian Hollingshead, assistant in genetics; Miss Priscilla Avery, preparator in botany; Mr. Chas. F. Poole, assistant in genetics.

HISTORY OF SCIENCE

Sarton, George, Cambridge, Massachusetts. *Associate in the history of science.* (For previous reports see Year Books Nos. 18-27.)

The present (eleventh) report covers the period July 1, 1928, to June 30, 1929.

1. *Introduction to the History and Philosophy of Science*—The final redaction of volume two is taking considerably more time than I had foreseen. This volume will cover the period extending from the twelfth to the thirteenth century inclusive. Thus far I have reached the middle of the thirteenth century. The part already written fills 1,443 typewritten pages, and is ready to be printed, subject to additions and corrections. However, it seems more expedient not to begin publication until the whole volume is ready.

Dr. Alexander Pogo, of the Yerkes Observatory, Williams Bay, Wisconsin, was appointed a Fellow of the Institution, to be my assistant, but his duties only began on July 1, 1929. He will work out the notes relative to the sixteenth century, which I have been collecting for more than fifteen years, and thus prepare the writing of volume four to be devoted to that century.

2. *The Publication of Isis*—During the past year I have edited five numbers of *Isis* (34 to 38) forming the end of vol. 10 (pages 329-528), vol. 11 (582 pages), and the beginning of vol. 12 (pages 1 to 450), a total of 1,232 pages, 27 plates. They contain 33 papers, 16 shorter communications, 52 reviews, 2,338 bibliographic notes.

3. *Lectures*—A course of some thirty-five lectures on the history of science was delivered at Harvard University, and another of the same length on the history of mathematics at Radcliffe College. To these two courses must be added a few special lectures, three at the University of Chicago, and one each at Mt. Holyoke College, Brown University and the Carnegie Institution.

INDIAN ART

Blish, Helen H., University of Nebraska, Lincoln, Nebraska. *Study of the art of the Plains Indians, with particular relation to work on a pictographic Sioux manuscript.*

The following report has been submitted as a result of studies undertaken by means of a grant from the Carnegie Corporation of New York to the Carnegie Institution of Washington for the above purpose.

Almost four weeks during the summer of 1928 were spent in field work on the Pine Ridge Reservation, South Dakota, and a few days on the Cheyenne River Reservation, South Dakota, securing detailed explanation of the Amos Bad Heart Bull Manuscript. It was impossible to secure the complete exposition in the time that could be spent in the field at that season, for the lines of investigation opened by the various portions of the pictured record are numerous and extensive. The following academic year was spent at the University of Nebraska incorporating field notes with those already obtained, and in gathering added material from published works and from the Oglala Dakotas, by correspondence, through John Colhoff, interpreter, and in generally carrying forward the work of investigation on the basis of the lines opened by the information gathered on the Reservation during the summer. The main body of the report is incorporated in a thesis, entitled the *Amos Bad Heart Bull Manuscript, a Native Pictographic Dakota Historical Record*, which has been presented to the University of Nebraska.

Incident to her work on the manuscript, Miss Blish prepared during the year a paper on Indian song, which is but a summary of previously published discussions by various authorities. Later a more original and thorough article on societies and rituals of the Plains Indians, entitled *Ethical Conceptions of the Plains Indians*, was prepared. This is based on the representative secret societies, dance ceremonies, and rituals of the Oglala Dakotas which are portrayed in the Bad Heart Bull manuscript. Miss Blish, as has not been done before, concerned herself in this interpretation only with the ethical aspects and implications of these institutions.

John Colhoff, able interpreter and assistant in field work, has spent his life on the Reservation. Dollie Bad Heart Bull, sister of the artist and present owner of the book, helped in every way possible. Samuel Charger, of the Sans Arc Dakotas at Cheyenne River Agency, South Dakota, furnished some information regarding that division of the tribe. The chief informants, however, have been the two old men, He Dog and Short Buffalo, both prominent in the old days and still highly respected tribesmen among the Oglala Dakotas.

MATHEMATICS

Dickson, L. E., University of Chicago, Chicago, Illinois. *Completion of special mathematical studies involving use of tables of fourth powers.* (For previous reports see Year Book Nos. 11 and 26.)

Gordan Pall, appointed Research Assistant under the Grant, successfully completed researches essential to my general program of investigations in the theory of numbers. Recently I published elaborate investigations of the problem to represent all positive integers n as sums of s values of any given quadratic function of x and E_s numbers 0 or 1, where E_s is independent of n . While that theory was complete when $s \geq 5$, there remained cases when $s=4$ for which my methods failed. Pall invented a method which is successful when $s=4$.

In the Transactions of the American Mathematical Society for January 1929, I found all ternary Null quadratic forms N which represent all integers. By similar methods, Pall determined all types of integers which are represented by any form N .

My extensions of Waring's theorem on fourth powers (Bull. Amer. Math. Soc., 1927) were checked to 4000 by the manuscript table by Lehmer of sums of fourth power.

These important results will be incorporated in a volume of *Researches in the Theory of Numbers*.

METEOROLOGY

Bjerknes, V., Oslo, Norway. *Preparation of a work on the application of the methods of hydrodynamics and thermodynamics in practical meteorology and hydrography.* (For previous reports see Year Books Nos. 5-27.)

Three papers were issued during the year (see Bibliography). Summaries of these papers were given in the previous report, two being then in press and the other in preparation. Very important progress has recently been made in the discovery of a new type of "cellular" waves, giving new views upon the problem of the cyclones, and at the same time upon the important problem of turbulence. The first germs of the discovery will be found in two of these papers, the full development must be reserved for further publications.

CELLULAR WAVES

What may be called "cellular" waves were discovered or at least first discussed theoretically by Lord Rayleigh¹ and Love.² These waves were found as a possible form of motion of a *heterogeneous* incompressible fluid, which may exist even when the fluid is contained between rigid horizontal planes.

The system of the lines of flow, which propagate through the fluid and define the wave-motion, contains *two* systems of straight lines: the well-known vertical lines of flow which follow each other at the distance of a half wave-length, and in addition to that a set of horizontal straight lines of flow, which, in connection with the vertical ones, define a *system of rectangular cells*—one for each half wave. These horizontal lines of flow are equidistant when the density of the fluid is an exponential function of the height. Without disturbing the motion we may solidify the horizontal planes defined by the horizontal lines of flow, but not the vertical lines of flow, which propagate through the fluid with the wave. But in case of standing waves, even the planes defined by the vertical lines of flow may be solidified. The simplest example of a standing wave-motion of cellular type is the oscillations of a heterogeneous salt solution which completely fills a rectangular box.

The energy of oscillation or of propagation is gravitational. During the standing oscillation the center of gravity of the mass in a cell moves up and down. During the propagation the center of gravity lies high in one cell, low in the next, and so on.

Now an elementary solution given in Solberg's paper, *Integrationen der atmosphärischen Störungsgleichungen. Erster Teil: Wellenbewegungen in rotierenden, inkompressiblen Flüssigkeitsschichten*, made him discover that waves of cellular type are possible even in a *homogeneous* incompressible fluid, provided that the rotation of the earth is taken into account. But as the internal motion within a cell can not in case of homogeneity raise or lower the center of gravity, the energy of propagation can not be gravitational; it is kinetic and due to the rotation of the earth. A very remarkable fact about these waves is that when the cell has the dimensions of a cyclone,

¹ Rayleigh: Proc. London Math. Soc., vol. 14, page 170. 1883.

² A. E. H. Love, *ibid.* 22, page 307. 1891.

the period and the velocity of propagation of the wave are also of the order of magnitude met with by cyclones.

In order to clear up the dynamical nature of this new type of cellular wave, the following elementary considerations have been made. Let a closed tube be given, limited by two coaxial cylindrical surfaces and two planes normal to the axis of the cylinders. The tube shall be completely filled with water, and the entire system shall rotate like a solid body round the axis. Fluid particles situated on the same line parallel to the axis will then be subject to the same centrifugal force. This gives a complete balance—nothing tends to modify the motion.

Then let all particles near the one plane face of the tube get impulses directed outward from the axis, and all particles near the other plane face impulses directed inward. By the principle of *areas*, a particle displaced outward will arrive at its new place with a velocity of circulation smaller than that belonging to the locality in the undisturbed motion; and a particle displaced inward will arrive at its new place with a velocity of circulation greater than that belonging to the locality. If then we compare the centrifugal force at points situated on the same parallel to the axis of rotation, we find an excess where the particles have been displaced inward and a deficit where they have been displaced outward. Thus, the more the particles are displaced, the more will the centrifugal force tend to revert their motion. Ultimately they will be forced to return, and then to pass their initial equilibrium distance from the axis with a certain velocity, and to continue beyond this distance. But then the defined excess and the deficit have interchanged: centrifugal force again tends to drive the particles back to their equilibrium distance from the axis. Thus an oscillation will follow which is torsional about a certain central circle in the tube. The rotational oscillations are superimposed upon the original rotation round the axis of the cylinder.

Modified forms of these oscillations are easily obtained. Let us imagine a number of meridian planes through the axis, which divide the circular tube into an even number of equal cells, and let the impulses be distributed according to a sinus law, producing torsional displacements of opposite direction from cell to cell. Now the fluid has the same power of performing torsional oscillations within each such cell as in the entire tube. Therefore *a train of waves will be produced, which propagates along the tube, analogous to torsional waves propagating along an elastic wire.* The meridian planes, which were imagined for the division into cells, will propagate with the waves as planes of no distortion. On the two sides of such a plane we have torsion in opposite directions. The propagation may go with or against the direction of rotation. Calculation shows that the angular velocity of propagation, counted relatively to the rotating system, may reach the double of the given angular velocity of the rotation of the system.

Then any homogeneous incompressible fluid mass may be considered which rotates like a solid body, with constant angular velocity round an axis. We may divide it into a set of tubes of the shape just considered, by a set of coaxial cylinders round the axis of rotation, and a set of equidistant

planes normal to the axis. If we solidify these surfaces and planes, the fluid mass contained in any tube may perform the torsional oscillations or propagate the torsional waves which we have defined. As the system of tubes is symmetric with respect to any of the plane surfaces of division, we may introduce the condition that even the motion shall be symmetric with respect to any of these planes (*i. e.*, the motion on the one side of such a plane shall be the reflected image of the motion on the other side). When this condition of symmetry is fulfilled, each of these planes will be subject to the same dynamical pressure from both sides, and the motion is not modified if these planes be taken away.

Then it will further be possible to adjust the radii of the coaxial cylinders, and the wave-motion in the spaces between them, in such a way that the angular wave-length and the angular velocity of propagation become the same in the spaces between the different coaxial cylindrical surfaces; and further so that the fluid will exert the same pressure from both sides against these cylindrical surfaces of separation. These surfaces then become superfluous and may be omitted: *we then get free cellular waves in the rotating fluid mass.* Dr. Solberg's calculations show that in this cellular wave-motion, the amplitudes of the waves and the radii of the cylinders are expressed in Bessel functions.

Then we may analyse in the same way the case of any *circular vortex*, in which the velocity of circulation is a function of the distance from the axis; we may as above divide the vortex into a system of tubes by coaxial cylinders and equidistant planes normal to the axis, discuss the motion in each tube, and examine the conditions under which the surface of separation may be omitted. The condition of symmetry will be sufficient for taking away the plane dividing surfaces, while it is a problem of analysis, which may be solved in sufficiently simple cases, to state under which conditions even the cylindrical surfaces are superfluous.

As to the motion within each tube, three cases are met with, depending upon the law according to which the velocity of circulation varies with the distance from the axis. The critical case is the variation according to the law r^{-1} , which defines the irrotational circulation. We thus find:

I. *Case of stability*—The velocity of circulation in the tube either increases outward, or if it increases inward, it is according to a slower rate than the law r^{-1} . The disturbing impulse has then the same effect as in the case of the solid rotation: we get an excess of centrifugal force where the particles have been displaced inward, and a deficit where they have been displaced outward.* The centrifugal force will force the displaced particles back to their initial equilibrium distance from the axis, and the fluid in the tube can perform torsional oscillations or propagate cellular waves analogous to the torsional waves in an elastic wire.

II. *Indifferent case*—The velocity of circulation in the tube increases inward precisely according to the law r^{-1} . A particle displaced outward or inward will then, by the principle of the *areas*, arrive everywhere with precisely the velocity of circulation belonging to the locality in the undisturbed motion. The displacement does not change the distribution of the centri-

fugal force, and this force will neither counteract nor favor the disturbance. It is a case corresponding to indifferent equilibrium in statics.

III. *Case of instability*—The velocity of circulation in the tube increases inward more rapidly than according to the law r^{-1} . A particle displaced outward as consequence of the radial disturbing impulse will then, by the principle of the *areas*, arrive at its new place with a velocity of circulation which is greater than that of the locality in case of the undisturbed motion, and a particle displaced inward will arrive with a smaller velocity of circulation. The result will be an excess of centrifugal force where displacement outward has taken place, and a deficit where the displacement has been inward. The centrifugal force will then no longer counteract, but accelerate the motion produced by the disturbing impulse. The particles will not return—we then have the case of instability.

In case I the dimensions of the tubes and the motions in them may be adjusted so that all walls separating the tubes can be omitted. In case III, in whatsoever way the dimensions of the tubes and the motions in them be adjusted, nothing but *turbulent motion* can follow when the walls are taken away.

PROBLEM OF TURBULENCE

It has long been known that a fluid medium like water can take two distinct kinds of motion, "laminar" motion and "turbulent" motion. All known solutions of the hydrodynamic equations represent laminar motions, while in actual experiments turbulent motion very often turns up instead of the expected laminar one. But in spite of all efforts of the ablest investigators it has not yet been possible to state theoretically the conditions under which the transition from laminar to turbulent motion takes place. Our ignorance concerning this point is generally considered the most awkward gap in our present knowledge of fluid motion.

The above derived results now lead to the following view as to the origin of turbulence. *Any disturbance of a given steady motion will produce cellular wave-motion at places where such waves are stable, and turbulence at places where such waves are unstable.* The stability depends upon the variation of the velocity as function of the radius of curvature r of the tubes. As far as can be seen from the given elementary developments (the full mathematical theory is being worked out by Dr. Solberg), proportionality of the velocity to the power r^{-1} will be the critical case of transition, higher negative powers giving all instability, and all other powers stability.

At the places of instability any disturbance will be sufficient for making the original laminar motion change into a turbulent one. And if at the boundaries of the regions of instability the new motion makes the conditions unstable, the turbulence will spread.

Turbulence is according to this view an effect of the *inertia* of the fluid, not of its *viscosity*. Viscosity will only have the power of reducing the intensity of the turbulence produced, thereby leaving great scale turbulence practically unchanged, but annihilating the smallest micro-turbulence. But in doing this, viscosity will at the same time contribute to the spreading of the turbulence in the fluid. The dependency of turbulence upon inertia.

not upon viscosity, easily explains the turbulence in the middle of the ocean, thousands of meters from the bottom, or in the atmosphere, thousands of meters above the ground, thus far off from the places of the strongest frictional effects.

If turbulence always originates from the instability of *curved* currents it is easily understood why the formidable efforts to solve the problem by starting with *straight* currents have failed. The origin of turbulence in rectilinear tubes or canals may then be this: when we go down to molecular dimensions, true rectilinear motions and true plane boundary surfaces do not exist. If we take into account the actual curvatures when we approach molecular dimensions, turbulence as a phenomenon of inertia should come up everywhere, both at boundary surfaces and in free fluid. Only viscosity extinguishes the smallest micro-turbulence and makes laminar motion possible.

A very interesting point in connection with the view upon turbulence thus arrived at is that it has been found under the search for a theory of cyclones. This may be more than purely accidental, there may be a close connection between the two problems. If we count with turbulence elements of dimensions ranging from the molecular to those of terrestrial cyclones or even of sun-spots, it may prove legitimate to identify the ideas of turbulence elements and of cyclones.

NUTRITION

Mendel, L. B., and H. B. Vickery, New Haven, Connecticut. *Continuation and extension of work on vegetable proteins.* (For previous reports see Year Books Nos. 3-27.)

In our earlier experiments on the promotion of growth by addition of "natural" foods to the so-called "synthetic" rations which had hitherto been regarded as almost, if not entirely, adequate for the nutrition of the albino rat, the use of certain green leaves was included. Lettuce, in particular, proved to be an advantageous dietary supplement. The quantities of lettuce requisite for inducing much more rapid gains than hitherto usual when the rest of the ration consisted of purified protein, starch, fats (including vitamins A and D), selected inorganic salts, and vitamin B as supplied by yeast, were considerable—amounting often to 20 grams of fresh vegetable per day. This is equivalent to 0.8 gm. of dry substance in the lettuce. A consideration of other sources of "greens" led us to a study of watercress, *Nasturtium officinale*. The small leaves of this plant contain, on the average, 8.53 per cent of dry substance. Of this 13.7 per cent is inorganic material and 5.9 per cent substance of fat-like character, soluble in ether.

With such a product, fed either fresh or after drying at a comparatively low temperature in a current of air, satisfactory gains were made on diets consisting of casein 35 per cent, salt mixture 4 per cent, butter fat 9 per cent, lard 15 per cent, starch 37 per cent, supplemented with 0.4 gm. dried liver and 0.4 gm. dried watercress (equivalent to 4 gm. of the fresh leaves) each day. Thus male rats of 60 gm. initial body weight tripled their size at the rate of 3 gm. increments per day in contrast to the "average" daily gains of 1.77 gm. To accomplish the same results, somewhat larger quantities of lettuce seem to be required.

Incidentally it became important to learn something about the vitamin content of watercress, in relation to its efficacy as a dietary supplement. The only previous study with which we are familiar is that by Coward and Eggleton¹ in England. They reported in 1928 that—

Watercress is a remarkably rich source of vitamin A, 0.1 gram only of the green leaf being necessary to promote normal growth in a rat which has become steady in weight on a diet lacking this factor only. It contains also small amounts of vitamin D. Its growth-promoting properties are even stronger in the spring and summer than in the winter. It is a very rich source of vitamin C, 1 gram daily being enough to protect guinea-pigs completely for a period of 70 days.

Our own experiments abundantly confirm the claims regarding the comparative richness of watercress in vitamin A; and this is true of the dried as well as of the fresh leaves. We have undertaken numerous so-called "curative" tests in which rats were kept on an otherwise adequate ration devoid of sources of vitamin A until marked symptoms of deficiency, as expressed in the actual appearance of xerophthalmia, ensued. Varied

¹ Katherine H. Coward and P. Eggleton: *The Content of Vitamins A and C in Watercress.* Lancet, 1, page 97. 1928.

portions of dried watercress leaves were then added daily and the condition of the animals observed for at least 80 days thereafter. The ophthalmia was often, though not invariably, cured by administration of 10 mg. of the dried leaves, equivalent to about 100 mg. of the fresh leaves. Presumably the fresh leaves would have been even more potent, inasmuch as some deterioration is likely to occur even under very careful conditions of open-air drying. Growth was not always vigorously resumed when 5 to 50 mg. daily doses were supplied; supplements of 100 mg., however, invariably effected cures and resumption of growth at a satisfactory rate. The "curative" method was employed because it represents a particularly severe test.

Watercress was also examined as a source of what was formerly called vitamin B, at present regarded as a mixture of two or more independent factors variously designated as B, B₁ or F and B₂ or G, the former equivalent to the so-called antineuritic vitamin. Our experiments indicate that all of these components are present in either fresh or desiccated watercress. A daily dose of 400 mg. usually suffices as the sole source of vitamin B (F + G) for small rats, up to 120 gm. body weight. After they grow larger the vitamin requirement increases, as we have already demonstrated in the case of yeast. The later stages of growth—up to 350 gm. in male rats—can often be accomplished at a satisfactory rate on daily allowances of 700 mg. dried watercress; more effectively on an intake of 1.0 gm. per day. In this respect, watercress is quantitatively somewhat more effective than lettuce. In all of our experiments the animals were kept on false-bottom cages to prevent access to their feces; hence the relative potency of watercress as a source of the vitamins can not be accurately compared with older experiments on green leaves when precautions of this sort were not taken. Examination of our animals by Professor Karl E. Mason of Vanderbilt University, now in progress, will indicate whether vitamin E also is present in the leaves of watercress. In any event the dietary virtues of this type of "greens" are now experimentally established.

Not long ago Fridericia of Copenhagen called attention to an apparent acquired immunity to deficiency of vitamin B in rats receiving a diet devoid of this vitamin group, but presumed to be adequate in all other respects. He stated that "In spite of the deprivation of B-vitamin a few of the rats resumed their normal rate of growth, and at the same time a change occurred in their intestinal tract, manifesting itself by their feces turning white and bulky. Eating of feces was prevented (wiregauze bottom in cages). Control rats, also fed on a diet devoid of B-vitamin, behaved in the usual way (growth stopping after 1 to 3 weeks, death after 4 to 5 weeks)." To the restoration phenomenon Fridericia gave the name "refection." Subsequently he described its manifestations in detail, including the characteristic high content of undigested uncooked rice starch in the "white" feces. The hypothesis was offered that multiplication of micro-organisms supplying vitamin B occurs in "refected" rats; hence the unexpected resumption of growth. By feeding the feces of "refected" individuals to other rats that were showing failure of growth on a B-free diet, "refection" could

often be induced and growth restored. The feces then always turned "white." Many additional surprising details have been recorded.

The "spontaneous cures" in rats reared on diets devoid of the vitamin-B components have also been reported from two laboratories in England. In hundreds of experiments with albino rats in the laboratories of both the Connecticut Agricultural Experiment Station and Yale University over a period of many years, we have failed to note any comparable phenomenon of "spontaneous growth" with production of bulky white feces when the animals were living on diets rich in raw starch and devoid of the plurality of food factors formerly described as vitamin B. The customary ration, which varied from time to time in the proportions of the ingredients according to the purpose of the tests, had a composition essentially as follows: protein 18 to 35 per cent, Osborne and Mendel salt mixture IV 4 per cent, fat 24 per cent, and the remainder corn starch. Cod liver oil was fed apart from this mixture, or else butter fat was included therein to supply fat-soluble vitamin. Latterly we have added small doses of irradiated ergosterol. Years ago we observed that rats, maintained a long time on mixtures of isolated foodstuffs, often ate their own feces. Feeding small quantities of rat feces to animals showing nutritive decline sometimes brought about a favorable response in restoration of weight. After the development of the vitamin hypothesis in the study of nutrition the favorable effects of feces were attributed to the presence of residual vitamins therein, perhaps of bacterial origin. The possibility of such a source is now generally recognized and has led to the use of special cage devices whereby access to the feces is prevented.

The significance of the "refection" phenomena reported abroad for all experiments involving biological examinations for vitamin B in foods or other chemical substances is obvious. We have considered it worth while to make observations on the possibility of "refection" in our laboratory by imitating somewhat closely the dietary conditions reported by the British experimenters, in contrast to our own customary feeding procedures. The appearance of "refection" in rats would preclude any satisfactory tests for certain vitamins in either food products or synthetic substances and thus raise doubt as to the validity of many experiments in animal feeding. We have failed to secure any cogent evidence of "refection" on the diets containing raw starches. The negative outcomes were gratifying.

The possible physiological importance of very small quantities of the salts of certain elements for well-being is being accorded widespread attention. The significance of iodine for the development and function of the thyroid gland is clearly demonstrated. The possible need or action of traces of other elements such as zinc, manganese, copper, arsenic, fluorine, silicon, etc., is by no means conclusively demonstrated, though it has occasionally been debated. Early in our studies of nutrition we devised a mixture of mineral nutrients in which were included very small amounts of iodine, manganese, fluorine and aluminium. The mixture has found widespread use in many laboratories throughout the world where feeding experiments on animals are conducted. It is by no means certain, however, that

the proportions of the individual elements or ions hitherto used are the most appropriate, if indeed they are essential. The almost inevitable contamination of food substances and chemicals with traces of some of the inorganic elements referred to complicates the problem of determining their possible rôle in nutrition. Recently it has been reported that larger quantities of iodine than those incorporated in our salt mixture IV produce beneficial results measured by the growth of rats to full adult size. We are reinvestigating this claim under the conditions existing in our laboratory; furthermore, a series of growth trials has been instituted to ascertain whether modifications of the currently used salt mixtures will be of advantage in nutrition experiments in which the inorganic nutrients must be added as such to the organic foodstuffs to secure an adequate ration.

Since the discovery of vitamin A there has rapidly developed an appreciation of the pathological conditions that may arise when there is a deficiency of this essential food factor. These include the now familiar xerophthalmia, calcareous concretions in the urinary tract, collections of pus in the inner ear, at the base of the tongue and elsewhere, and keratinization of many of the epithelial tissues. There is a current impression that somehow a deficiency of vitamin A in the diet tends to reduce the "resistance" of the body to infections. The mechanism of this diminished immunity has never been clearly demonstrated, if indeed the implied susceptibility does arise. Inasmuch as "lung disease" is of frequent occurrence in rat colonies we attempted to ascertain whether a relative shortage of vitamin A in the diet would alter the incidence of the rat malady. Two lots of rats ranging from 37 to 83 days of age were kept for 75 days on otherwise adequate diets varying only with respect to the quantity of vitamin A supplied in butter fat. For one lot the ration included 1 to 1.5 per cent of butter fat, a quantity below the requirement for good growth and well-being; the other lot received a satisfactory supply of vitamin A represented by 9 per cent of butter fat in the ration. The latter group continued to grow far better than the rats on the poorer ration. At autopsy some of the animals deprived of their full complement of the potent butter fat gave microscopic evidences of familiar abnormalities such as accumulations of pus at the base of the tongue and renal calculi. Lung defects were not observed in any case. More recent experiments at Yale University have indicated that the pulmonary caseous masses so familiar to observers of rats at autopsy probably have their explanation in preliminary changes leading to atelectasis of individual lobes through mucus and have no immediate connection with diet.

The collaboration with Dr. Francis G. Benedict of the Nutrition Laboratory in the study of the respiratory metabolism of the rat has continued effectively with the equipment assembled in Professor Mendel's laboratory in Yale University. The apparatus, which includes specially devised respiration chambers for rats, and also a constant temperature cubicle in which the animals may be kept over long periods at selected temperatures, has been thoroughly tested and employed to secure the "norms" desired for subsequent comparisons. Thus the basal metabolic rate of the rat, and the

possible modifications dependent upon age, sex, environmental temperature, etc., have been extensively studied. The effects of prolonged delays in growth and of marked variations in the rate of gain during the developmental period are under investigation. The animals have been taken from our long-established colony and have been fed in our laboratory so as to secure the conditions desired for each project. The results of this continuing investigation will be reported in detail by Dr. Benedict.

In the report for 1926-1927 a method was outlined for the study of the development of the bones in rats, particularly with reference to the deposition and metabolism of calcium and phosphorus therein. The food formula there detailed, involving as far as possible mixtures of isolated substances of which each could be varied in quantity as desired, has proved of value. Further plans were reviewed in the report for 1927-1928 and many of the experimental projects there outlined have already been undertaken. The production of animals exhibiting serious osseous defects has been impeded in many instances by the protective devices of the individual. These include the failure to eat adequately, an attendant retardation or even complete cessation of growth, and the consequent protection of the organism from enforced pathologic changes that ensue when growth of the body as a whole proceeds. We have found it more difficult to secure marked rachitic or related changes on our purified food mixtures than is the case with the conventional rickets-producing diets now in use for testing for vitamin D. The latter are, however, presumably deficient in several respects, and therefore have seemed to us less likely to permit discriminating answers to some of the questions at issue. The investigation is being continued with the collaboration of Professor E. A. Park who is now attached to the Johns Hopkins Medical School.

The details of the extensive study of the relation of diet to fertility as expressed in the assumption of a specific dietary factor—vitamin E—which Dr. Karl E. Mason, now of Vanderbilt University, began several years ago in cooperation with us, have been published. In addition to the findings reviewed in the report for 1926-1927 certain further tentative conclusions seem justified. Dr. Mason writes:

"That the germ cells of the male rat require a definite amount of vitamin E for their complete metamorphosis would seem assured—providing adequate amounts of the vitamins A, B and D are supplied. Yet it seems difficult to conceive of the same factor having no relation to germ-cell maturation, ovulation or implantation in the female; but performing here a definite function in relation to placentation and embryonic development, as has been set forth by Evans and Burr. . . . However, the observations of various investigators of dietary sterility have failed to give any indication that the same factor—vitamin E—is not responsible and necessary for the maintenance of fertility in both the male and female rat. In fact, the results of various investigators indicate that the dietary cause of sterility, the vitamin E requirement for fertility, the storage of vitamin E in the tissues of the body and the 'initial fertility' observed on rats reared from weaning on inadequate diets, are practically identical in both sexes, regardless of the marked differences in the histo-pathological manifestations of the 'sterility disease.'"

Thus Mason is led to assume that "vitamin E is a specific requirement of the germinal epithelium of the testis," and that "lack of this factor has no demonstrated effect on any other organ or tissue of the body."

Inasmuch as relationships between vitamin E and iron assimilation have been alleged to occur, a number of comparisons between the total erythrocyte count and total hemoglobin content of the blood in male rats fed diets deficient and diets abundant in vitamin E have been made on our rats. Although repeated estimations were made on the same animals, at various intervals, the erythrocyte and the hemoglobin content were normal in all cases studied. We believe that the earlier assumptions must be abandoned.

The last two reports have contained references to our studies of the problem of maximal or optimal growth versus "ordinary" growth in the albino rat. It still remains to be determined whether even more rapid gains than those recorded can be brought about in the growing young of our stock through dietary measures. Experiments directed to this end are now in progress. If better methods of securing maximal gains are discovered, the investigation must be extended to include simultaneous measurements and examination of various important organs and tissues. From the chemical standpoint the discovery of effective substances in promoting unusual types or speeds of growth is always one goal. The results attained, involving a tripling of the rate of gain during the usual periods of most active growth after weaning in contrast with the hitherto recorded "average" rates for the same species, present various uncertain implications. It by no means follows, for example, that an animal which has made very rapid gains as the result of appropriate feeding represents a more ideal state of nutrition or physiological development than that of an individual growing at more nearly the "average" rate. Apart from the differences due to hereditary factors as expressed in "breed" or "strains," many questions as to the proper correlation between size and age arise. The functional development of such glands as the thyroid and the gonads in animals of the same parentage and age but widely differing in attained size may be considered. It has been alleged by students of child development that chronological age is a more important factor than mere growth in size in the acquisition of characteristic types of behavior in the adolescents. Our methods of growing genetically related animals at varying rates of gain now make it possible to attack some of these problems in the development of behavior.

Our investigations of the basic amino acids yielded by proteins after complete hydrolysis by strong acids have been continued with the objects of improving existing methods of preparation and also of extending the application of the improved procedure for base analysis to other proteins. As mentioned in last year's report we have applied the method of silver precipitation to the large scale preparation of histidine. Although a variety of techniques for the preparation of this amino acid have been published, experience with some of them has shown that unaccountable variations in the quality and yield of the product frequently occur. Nearly all of the older methods depend upon the precipitation of histidine by mercuric chloride and sodium carbonate. The ease with which histidine can be

precipitated as its silver compound at or near pH 7.0 and subsequently freed from most of the accompanying amino acids by precipitation with mercuric sulphate in acid solution, suggested that these reactions were better suited for large scale work than the reaction formerly recommended. It has also been found that free histidine can be readily crystallized from 50 per cent alcohol provided that the solution is previously adjusted to a reaction of pH 7.2 which is close to the isoelectric point of this amino acid. This has enabled us to isolate fairly pure histidine from red-blood cells directly as the free base at the end of only four main operations—hydrolysis of the protein, silver precipitation, mercuric sulphate precipitation and crystallization of the final product. Subsequent purification was effected by crystallization of the dichloride, and the pure free base was finally secured from the dichloride by neutralizing to pH 7.2 with magnesium oxide, taking advantage of the solubility of magnesium chloride in alcohol. This final procedure illustrates a principle we have found extremely useful in dealing with amino acids, namely that the crystallization of two different compounds is advisable in order to purify these amphoteric substances. In this way the accompanying amino acid impurities are left in one or other of the mother liquors.

The modified Kossel method for the determination of the basic amino acids has been previously applied to edestin, a protein which contains a high proportion of arginine, and a low proportion of histidine. This was referred to in last year's report. We have now applied the method to crystallized horse hemoglobin, a protein of high histidine and low arginine content, with the object of devising such modifications as might be necessary in dealing with the special problems thereby presented. We are indebted to Dr. E. J. Cohn of the Harvard Medical School for an extraordinarily fine preparation of this protein. It has been found that the separation from the arginine of the main quantity of the histidine derived from hemoglobin, is best effected at a slightly more alkaline reaction than has hitherto been employed, namely pH 7.4. In order to make certain that no appreciable amount of arginine had found its way into the histidine fraction so prepared we looked for this base in the filtrate from the precipitation of the histidine with Hopkins' reagent. The small amount that was found we attribute to the difficulty of washing the voluminous precipitates completely. In this analysis every possible precaution was taken to effect complete separation of each basic amino acid. The purity of the final fractions secured was highly gratifying and indicated that by proper attention to the details of the procedure it is possible to carry out a basic amino acid analysis with something approaching the accuracy required by the modern physico-chemical theory of proteins. The results of this analysis indicated that horse hemoglobin yields 7.64 per cent of histidine, 3.32 per cent of arginine and 8.10 per cent of lysine. It is interesting to note that these results are in closest agreement with the assumption that the hemoglobin molecule, the molecular weight of which is known with some accuracy to be 66,800, yields 33 molecules of histidine, 13 of arginine and 37 of lysine. The hemoglobin molecule contains 4 atoms of iron and 8 of sulphur. There has for some time been a feeling that it may be formed by the aggregation

of four parts, each containing one atom of iron. If the above analysis is as trustworthy as we believe it to be, it is clear that these four parts can not be symmetrically constituted since the molecular proportions found are not divisible by four.

The recent discovery of ergothioneine in human and in pig's blood by two independent groups of workers was followed last year by the observation by Eagles and Vars that the ergothioneine usually present in pig's blood may owe its origin to a hitherto unappreciated dietary factor. When young pigs were nourished on a diet containing casein as the sole protein, ergothioneine could not be detected in the blood. This substance appeared, however, when corn was substituted for the casein as the source of protein. This led to an examination of the proteins of corn for a substance responding to the characteristic thiol-imidazole color test which is given by ergothioneine. After complete hydrolysis highly purified zein was found by Doctors Eagles and Vars to give a pronounced positive reaction; as a result of this we invited them to pursue in our laboratory the search for the substance giving rise to it. Our interest in ergothioneine arises from the fact that this substance is the betaine of thiol-histidine. The animal body is known to have the capacity to methylate certain basic substances and it therefore appeared likely that the precursor of ergothioneine is thiol-histidine and that this substance may be a constituent of a number of proteins, in particular of zein. An intensive search for thiol-histidine in zein was carried on for a number of weeks up to the time of Dr. Eagles' departure for Europe last year and the investigation has been continued this summer. Although considerable useful information has been obtained, the search has been unsuccessful. We are satisfied that zein contains a substance responding to the supposedly specific thiol-imidazole test of Hunter, but the compound appears to be so unstable under the conditions that we have employed that its isolation will have to await the development of more suitable methods. The importance of this problem can hardly be overestimated. At the present time cystine and methionine are the only known sulphur-containing amino acid constituents of proteins. With the possible exception of certain keratins, such as those of wool and of hair, the sulphur content of no protein can be wholly accounted for in terms of these two amino acids alone. There is therefore reason to suppose that other sulphur-containing amino acids exist and the search for these provides one of the most intriguing problems of modern protein chemistry.

An important by-product of our investigation of zein was the observation that cystine is precipitated as a silver compound at reactions in the range pH 1 to pH 6. Since cystine is likewise precipitated by every heavy metal reagent employed to precipitate histidine, it is obvious that it may find its way into histidine fractions secured by the customary methods. We have therefore spent much time upon a general investigation of the methods of preparation of cystine and upon its properties. Although no improvements in the method of preparation of sufficient novelty to warrant special publication have been made, we have found that an extraordinarily fine product can be secured by crystallizing cystine from its solution in hydrochloric acid with the aid of alcohol. Under these conditions it separates in a yield

of from 60 to 70 per cent in very finely developed large plate crystals. The cystine remaining in the acid mother liquor can be recovered by neutralization and the process of crystallization repeated.

A convenient procedure whereby any cystine present in histidine fractions derived from proteins can be removed has been developed. This depends upon the great insolubility of the copper salt of cystine. This device has been employed in an examination of the basic amino acids of human hair which was undertaken with the view to extending our analytical investigations to a protein with high cystine and low histidine content. The results of this study are in press.

We have to record the failure of an attempt to isolate still another new amino acid from proteins. Some years ago Schryver reported that oxy-amino-butyric acid was present in casein and more recently Rimington isolated a phosphorus-containing peptide from casein which appeared to contain this same acid. It seemed worth while therefore to attempt its isolation by the well-known Fischer method, inasmuch as it seemed probable that the acid should be present along with serine in the distillation residue from the esters. A careful study of the distillation residue secured from a kilogram of casein failed to reveal the new acid, but it was found that this residue is so complex a mixture of amino acids together with diketopiperazines that the isolation from it of a substance of the properties ascribed to oxy-amino-butyric acid would be to a large extent a matter of luck. Although the primary object of the investigation failed, a number of indications for possible improvements of the technique of dealing with amino acid esters were noted.

The investigation of methods for the determination of the nitrogenous constituents of green leaf-tissue has been actively continued during the year with the able assistance of Dr. G. W. Pucher of the Connecticut Agricultural Experiment Station staff, who is attached to our laboratory. As mentioned last year we are devoting our attention to the tobacco leaf in part because of its economic importance in Connecticut and the ease with which suitable material may be secured at this Station, and also because of the unusual chemical problems presented by a tissue in which a large proportion of the water-soluble nitrogen may occur in the form of the relatively strong base nicotine. Papers now in press describe new methods for the determination of nitrate nitrogen and also of ammonia and amide nitrogen in tobacco. The special difficulty of these determinations arising from the presence of the volatile alkaloid have already been pointed out. Before attempting the determination of the nitrate in tobacco leaf it has been found necessary to remove all volatile basic substances from the sample by steam distillation from strongly alkaline solution. The nitrate in the residue is then reduced to ammonia and determined. Detailed examination of a number of procedures has shown that the Jones method, in which nitrate is reduced by the action of acid on so-called "reduced iron powder," is the most suitable. The ammonia produced is subsequently estimated by distillation and titration. If the Jones method is applied to tobacco leaf or extracts without previously removing nicotine a blank determination must be carried through the whole operation employing every reagent except the

reduced iron powder. The magnitude of the blank so obtained frequently exceeds 50 per cent of the determination. Moreover, since nicotine is only partially distilled under conditions that remove ammonia completely, both blank and determination must be distilled at precisely the same rate and for the same length of time as, otherwise, appreciable errors may occur in the estimation of the nitrate nitrogen. This difficulty has been largely obviated under the conditions we have adopted. It is still necessary to carry out a blank determination, but its magnitude is relatively small and no particular precautions are necessary to conduct the parallel distillations under exactly the same conditions.

When the modified Jones method is applied to tobacco grown under widely different conditions it has been found that the proportion of nitrate nitrogen may vary from zero to over 50 per cent of the total water-soluble nitrogen of the leaf. The proportion of nitrate is thus highly dependent upon the conditions under which the tobacco has been grown and it seems very likely that the simple method we now have may prove useful in the investigation of conditions under which tobacco leaf of controlled nitrate content can be produced should this become desirable.

A number of methods have been suggested for the determination of the ammonia and amide nitrogen content of tobacco leaf. Most of these are troublesome and time-consuming and involve corrections for the presence of nicotine. We have therefore devoted much study to the development of a procedure that is at the same time rapid and accurate. The observations that nicotine does not undergo base exchange with permittit to any significant extent and also does not give a color with Nessler's reagent that interferes with the accurate colorimetric determination of ammonia led to the desired end. It has been found that the entire ammonia content of tobacco-leaf extract can be quantitatively distilled from a solution containing an excess of magnesia according to the technique employed by Folin and Wright in the analysis of urine. Some nicotine passes over but this does not interfere with the subsequent operations. The ammonia in the distillate is taken up on permittit according to Folin's well-known method and determined colorimetrically by Nessler's reagent. Inasmuch as trimethylamine is found in many leaf tissues and may be present in tobacco, a careful investigation was made of the behavior of methyl amines toward permittit. It was found that, provided these were not present in excessive amounts, the amines did not interfere with the accuracy of an ammonia determination.

The determination of the amide nitrogen of tobacco-leaf extracts is simple, once an accurate method for ammonia nitrogen has been found. Since asparagine, the most widely distributed amide in green leaf-tissue is hydrolyzed to aspartic acid and ammonia by boiling for 3 hours with 4 per cent hydrochloric acid (Sachsse), it is necessary only to carry out such an hydrolysis upon a sample of extract of known preformed ammonia content and determine the increase in ammonia by the above-described method. Considerable time has also been expended on a study of the properties of nicotine. Highly purified specimens have been prepared and the dissocia-

tion constants have been determined. A paper describing this work is in preparation. The investigation of the tobacco leaf is being continued.

We have been privileged in the course of the year to facilitate the investigations of several other workers by furnishing preparations of amino acids and of proteins. Professor C. L. A. Schmidt has carried out determinations of the acid and basic dissociation constants of valine and histidine using preparations procured from us. Mr. George L. Keenan has studied the optical properties of our crystallized arginine and histidine. Professor E. J. Cohn has been supplied with pure edestin solutions for his work on the physico-chemical properties of proteins.

Williams, R. R., and Walter H. Eddy, Teachers College, Columbia University, New York, N. Y. *Physiological functions of vitamins*. (For previous reports see Year Book No. 27.)

The following report is submitted as a result of studies continued with support of funds authorized by the Carnegie Corporation of New York to the Carnegie Institution of Washington for a three-year period beginning April 1927.

Upon the occasion of our report for 1927-28 we referred to the evidence of the existence of no less than four distinct factors which contribute to the sum total of beneficial physiological effects which have been widely and rather generally recognized as attributes of vitamin B. This multiplicity is one of the considerations which have led us to adhere to the nomenclature adopted by the British biochemists whereby the several components of what has been called vitamin B are distinguished by subnumerals attached to the letter B. From our viewpoint the problem is an analytical one, the successful solution of which will enable us to separate each significant physiological entity from every other and assign proper physiological effects to each. Since many, if not all, the physiological effects which we hope to recognize for each component are already recognized as effects of the composite B, we avoid the implication of the discovery of a new vitamin which the use of the terms vitamins J, K, etc., would involve.

In reporting the year's progress we may well do so by discussing each of the four supposed B factors seriatim.

THE VITAMIN B COMPLEX

Vitamin B₁, or the antineuritic vitamin, has been far better characterized chemically than any other B factor. The most advanced piece of chemical work in this field is that of Jansen and Donath¹ who reported the isolation of a pure substance of antineuritic properties. Last year we attempted to apply their methods to the fractionation of yeast with but meager success. During the present year we have repeated their work on rice polishings with more encouraging results but without, however, securing full confirmation of their claims. As in the case of yeast fractionation, the dissipation of activity by losses in fractions to be discarded is greater than indicated by Jansen and Donath. In addition the losses by apparent destruction are vastly greater, so that whereas Jansen and Donath claimed a recovery of

¹ B. C. P. Jansen and W. F. Donath. *Mededeel. Dienst. Volkgezondheid, Nederland, Indie*, Part 1, page 186. 1926.

25 per cent of the original activity in the filtrate from platinum sulfide, our own recovery at that stage is a bare 5 per cent. It is clear in our own experiments that these losses take place not in the process of leaching the polishings nor in adsorption upon acid clay, but in later stages and probably in those involving the use of alkali. The initial steps of the process are remarkably efficient. The acid clay used by Jansen and Donath¹ appeared decidedly superior to our supply of English fullers earth, both in selective adsorption capacity and in completeness of release of activity on treatment with alkali.

A large part of the discrepancies between our estimates of recoveries and those of Jansen and Donath may be due to differences in the method of physiological testing. They used rice birds on a polished rice diet for the great part and evidently depended to a large extent upon the lapse of time before incidence of polyneuritic symptoms as a quantitative measure of activity. We can not accept lapse of time as such a measure without further substantiating evidence. Our experience with fowls and pigeons indicates wide individual variations on identical diet as to time of onset of forth-right symptoms. Our own method in these experiments was to determine by trial the minimum dose of each fraction required to afford complete protection to four pigeons (previously depleted of antineuritic vitamin) against any occurrence of polyneuritic symptoms during a 30 to 40-day feeding test on polished rice. In each case we confirmed our result by a 60-day feeding test on three young rats using a diet² which invariably produced unmistakable symptoms of polyneuritis in controls. It may be of interest to note that in comparisons of some scores of preparations we have found that the daily dose of antineuritic required by the young rat will ordinarily just serve to prevent polyneuritis in a pigeon if given every other day. Per unit of weight, the young rat seems to require about ten times as much antineuritic as the adult pigeon.

In following the Jansen and Donath fractionation, we have been impressed by the qualitative correspondence of their observations with our own. Each step has proceeded as described by them and with few exceptions their comparative ratings of their several fractions as to activity correspond well with our comparative ratings of our own fractions. The final stages of fractionation with alcohol and acetone proceed exactly as they describe. Purification of our final product is not yet complete as the process is extremely slow as well as wasteful. We will therefore reserve a report upon the final product as well as further details of the procedure and results for future publication.

From the physiological standpoint the above work seems very significant. Jansen and Donath report that their final crystalline product fully protected pigeons from polyneuritis upon a polished rice diet for a period of six weeks, not, however, without rather substantial losses in weight in some cases. The addition of meat protein did not serve to obviate entirely this weight loss in their experiments. No weight curves are given by them, though it would be of great interest to know whether or not the losses

¹ Kindly supplied us by Dr. B. C. P. Jansen.

² H. C. Sherman and A. J. Spohn. *Amer. Chem. Soc.*, vol. 45, page 2720. 1923.

occurred only in the early stages and were followed by a period of maintenance at a subnormal level as has been the case in our experiments with intermediate fractions. However, our interpretation of their pigeon results as well as of our own experiments is that the antineuritic vitamin, while capable of preventing polyneuritis, is not the sole vitamin present in the original rice polish which has a significance for birds. The missing substance is what we have designated provisionally as the "third factor" or B₃.

So far as we can ascertain, our own studies have been the only ones in which the Jansen and Donath work has been exactly duplicated. Peters reported a study of the application of the method to yeast and met difficulties and variations similar to ours when that source was used. Drummond and Guha have carried out the method with wheat embryo but introduced a variant in the final steps. A preliminary report was made by Guha and Drummond,¹ but their study is not yet fully completed. On arrival at the platinum precipitate they had obtained a concentrate that was curative of polyneuritis in pigeons with daily doses of 0.005 mgm. At this point they felt that separation of the active vitamin in pure form would be better accomplished by forming a derivative rather than by differential solution and precipitation with alcohol and acetone. They therefore introduced gold chloride at this point with interesting results. The gold chloride precipitate in a limited number of experiments was partially active for rats and the gold chloride filtrate totally inactive, but when the gold precipitate and filtrate were combined in the diet of rats a much greater activity was obtained than with the gold precipitate alone. They therefore tentatively postulate a duality of substances obtained at the platinum precipitation stage. However, as they were seeking the factors that influence rat behavior and as their experiments are as yet incomplete, we can not tell whether this second factor is in any way related to our B₃ factor. Funk,² however, by use of his vitamin equilibrium testing method with pigeons confirms our belief in the existence of a pigeon weight-maintaining factor separate from the antineuritic factor.

For the sake of gaining further insight into the physiological purity of Jansen and Donath's product we have compared fractions from the advanced stages of their procedure with antineuritic preparations of other origin. The Kinnersley and Peters³ procedure, down through the stage of removal from norite, has been applied repeatedly to both bakers and brewers yeast and the product used as antineuritic complement for both rats and pigeons. For pigeons these fractions are the equivalent of the Jansen and Donath substance, prophylactic against polyneuritis but deficient in weight-maintaining power. In the case of rats, however, the Peters' product, especially in larger doses, permits some measure of growth which is not the case with the Jansen and Donath products. A careful study of our own activated fullers earth product⁴ indicates that it also differs from that of Jansen and Donath in permitting some growth in young

¹ B. C. Guha and J. C. Drummond. Abstract paper before English Biochem. Soc., Mar. 15, 1929, in *Jour. Chem. Indus.* 1929.

² Casimir Funk. Personal communication.

³ H. W. Kinnersley and R. A. Peters. *Biochem. Jour.*, vol. 21, page 277. 1927.

⁴ R. R. Williams and R. E. Waterman. *Jour. Biol. Chem.*, vol. 78, page 311. 1928.

rats. We therefore believe that while the antineuritic vitamin is common to all these preparations and represents their major constituent physiologically, only the Jansen and Donath substance approaches a high degree of physiological purity.

We may also note here that some preliminary studies of growing chicks, as yet incomplete, seem to indicate that the chick like the pigeon requires the B₂ factor for growth and weight maintenance in addition to vitamin B₁.

Vitamin B₂ has been described as the pellagra preventing vitamin which is present in autoclaved yeast and therefore to some extent thermostable. It has also been credited with favorable influence on the growth of young rats which is doubtless true in some measure. However, since no one has described a pellagra-preventing preparation that has undergone any extended attempt at chemical fractionation, it is impossible to say at present to what extent the pellagra-preventing property and the rat growth-promoting property are locked up in one molecular species. This question requires also an extended consideration from the pathological side.

Denton¹ has compared the histology of epithelia of various regions as found in rats on a B₂ deficient diet, in dogs suffering with black tongue, and in human pellagrins. His viewpoint seems to be that the pathology is the same in the three species, that in each case there is deficiency of some nutritional factor that is necessary to the foundation membranes. In its absence the changes in epithelia follow and are similar in type. It may be possible to utilize his data to sharply separate the factor of pellagric type from growth effects due to factors other than vitamin B₂ if we reserve that term for the antipellagric vitamin. Aykroyd and Roscoe² have recently reported data that seem to support Denton and others in believing that black tongue and pellagra are similar in origin. Today, however, pellagra in rats remains a rather ill-defined condition which may represent the result of multiple deficiencies, while if we turn to another animal species for study we are confronted with relative paucity of knowledge about fundamental nutritional requirements. We have felt that a true analysis of the pathological picture awaits a diet adequate in B₂ and totally devoid of other B factors. We have attempted a beginning in this direction by enquiring whether the traditional source of B₂, *viz*, autoclaved yeast, is physiologically reproducible.

This question has been tentatively answered in the negative, for wide variations in growth are produced by feeding of different lots of autoclaved yeast. Autoclaving may either fail to destroy B₁, or may serve to destroy B₂ as well as B₁, according to the conditions observed. In no case so far as we know is B₁ completely destroyed without also destroying a substantial fraction of B₂. We are thus left without an approximately standardized starting material. This confirms the results of Chick and Roscoe.³ Our experiments in this direction are more fully discussed elsewhere.⁴

As a substitute for autoclaved yeast we have tried Liebig's beef extract. This material seems almost if not quite devoid of B₁ as polyneuritis

¹ James Denton. *Amer. Jour. Path.*, vol. 4, 341. 1928.

² W. R. Aykroyd and M. H. Roscoe. *Biochem. Jour.*, vol. 23, 483. 1929.

³ H. Chick and M. H. Roscoe. *Biochem. Jour.*, xxii, 790. 1928.

⁴ R. R. Williams, R. E. Waterman and S. Gurin. *Jour. Biol. Chem.*, vol. 83, page 321. 1929.

promptly appears in rats receiving as much as 500 mgs. daily. When supplemented by B_1 in the form of our activated fullers earth it yields fair but distinctly subnormal growth in rats.

We have also attempted an answer by chemically fractionating autolyzed yeast extract. The yeast extract was brought up to 66 per cent alcoholic strength and precipitated with baryta. The baryta precipitate carried down about 30 per cent of the activity. The filtrate containing about 70 per cent of the activity was precipitated with mercuric chloride. The filtrate from this precipitation was devoid of B_2 . The mercuric chloride precipitate, after decomposition with hydrogen sulfide, was found by feeding experiment to be not quite free of B_1 . When supplemented with adequate B_1 it caused a substantial but subnormal growth of rats in doses of 5 to 10 mgm. of solids. The deficiency appeared to be qualitative as it was not remedied by increase of dosage.

By using such chemical fractions of yeast and meat extract in various combinations with the several forms of B_1 noted above, we are endeavoring to establish supplementary relationships as to the growth of rats which together with observations as to symptomatology may lead to a definite hypothesis as to the relationship of the pellagra preventing and growth-producing substances. The details of the more significant experiments will be published from time to time.

Vitamin B_3 has been described¹ as a highly thermolabile substance of no known significance to young rats but which, however, permits the maintenance of normal weight in pigeons on polished rice supplemented by adequate B_1 . It has been found by us to be present in abundance though in variable amounts in brewers and bakers yeast, the former being the richer source. We also find it in our studies of the past year in rice polish, wheat germ, whole barley, malted barley, autolysed yeast extract, beef liver and beef muscle. Very meager amounts were present in milk, wheat bran, malt extract, cane molasses, spinach, orange juice, tomato juice and potato juice. No known source is as rich in this B_3 as brewers yeast which supplies a full complement to pigeons in daily doses of 0.25 to 0.5 grams. Malted grains afford a very interesting source of this material on account of its possible relation to the antiscorbutic vitamin C, which has been demonstrated to develop in grains in the process of sprouting. Somewhat like vitamin C, B_3 is very thermolabile and is largely destroyed in yeast by heating at 60° C. Since commercial malt is dried at this temperature it is not a good source of B_3 and a special study of sprouting and drying conditions is in progress to determine whether B_3 is formed during sprouting or only persists through it. The sprouts themselves appear to lack this factor. The testing for B_3 is greatly complicated by the simultaneous presence of B_1 in all raw materials so far studied. Unless one happens to preponderate greatly, close distinction between B_1 and B_3 is impracticable.

The fate of B_3 , on treating its solutions with fullers earth and on treatment of activated fullers earth with alkali, remains to be studied more rigorously but our examination of the various products in the Jansen and Donath fractions of rice polish which are referred to above indicates that

¹ R. R. Williams and R. E. Waterman. Jour. Biol. Chem., vol. 78, page 311. 1928.

most of it, but not quite all, is destroyed or adheres in physiologically inert form to the earth. By separate experiments we have shown that B₂ is destroyed by cold alkali.

The problem of vitamin B₄ has already been discussed to some extent in the account of the experiments on B₂. Kennedy and Palmer¹ are we believe the first to suggest the existence of such a factor as essential to rat growth. Other workers have reported observations that may be taken as evidence of the existence of rat growth-factors not at present included in the vitamin lists. Chick² for example has found a difference between casein and egg white as sources of protein which she believes suggests a factor in the former and missing in the latter. Coward³ and Honeywell, Dutcher and Ely⁴ reported variation in vitamin A experiments, due in the one case to variation in casein quality and in the latter to variation in yeast. While the work of these two groups suggests something like vitamin A rather than B, the substance postulated is at least a variant from recognized rat growth-factors. From our own tests we note that while combinations such as autoclaved yeast with beef extract clearly have the property of improving the condition of rats receiving at the same time adequate B₁ and free of pellagra symptoms, yet they are qualitatively lacking in something necessary to normal growth and full health.

C. H. Hunt⁵ has published experiments which appear to offer tangible evidence of the multiple nature of the physiologically important constituents of autoclaved yeast. He digested yeast with water in such a way as to produce a filtrate and a residue, neither of which independently supported normal growth but which supplemented one another very efficiently in producing such a growth. We have repeated his experiments three times, varying the details as the situation seemed to demand, but have uniformly failed to detect any trace of the supplementary relationship which Hunt describes. Our extract and our residue have each independently invariably afforded good growth by appropriate and moderate increase of dosage. By correspondence with Dr. Hunt we learn that his success in the preparation of residues of the properties described has not been uniformly successful. The work of Guha and Drummond already referred to⁶ is the only other case of supplementary relationship that has come to our attention.

It remains to refer to the synthetic approach to the chemistry of vitamin B₁ which was mentioned in our report of last year. This work has not been abandoned but postponed. It seems idle to continue it until we can supply our rats with a diet which lacks only the B₁ factor. Without such a diet we find ourselves ever at loss to know whether the apparent deficiencies of a synthetic preparation are due wholly to its dissimilarity to B₁ or partly

¹ Kennedy and Palmer. *Jour. Biol. Chem.*, vol. 74, page 591, 1927; and vol. 75, page 619, 1927.

² H. Chick. *Biochem. Jour.* 1929.

³ K. Coward, K. M. Key and B. C. G. Morgan. *Abstracts International Physiol. Congress*, page 57. August 1929.

⁴ H. E. Honeywell, R. A. Dutcher and J. O. Ely. *Abstracts International Physiol. Congress*, page 127. August 1929.

⁵ C. H. Hunt. *Jour. Biol. Chem.*, vol. 77, page 723. 1928.

⁶ B. C. Guha and J. C. Drummond. Abstract paper before English Biochem. Soc., Mar. 15, 1929, in *Jour. Chem. Indus.* 1929.

to other subsidiary deficiencies of the diet. We have already indicated our lack of a B₂ preparation which is free of B₁ and thus possible of use in pigeon tests to supplement polished rice. In the case of rat diets, we are in even worse condition as autoclaved yeast is neither free from B₁ nor will it support full normal growth when supplemented with B₁. In fact we must admit to date no completely satisfactory test for quantitative measurement of even the oldest and best known of the vitamins.

Bios

In spite of the fact that neither the Bios 223 which we isolated in 1924¹ nor the beta-bios reported by Kerr in 1928² seems to have any place in animal nutrition, we have not entirely abandoned the hope that the study of the bios problem may ultimately throw light on the vitamin B problem. To that end we have continued our work on the chemistry of these substances and of the problem of Wildier's Bios in general. Our own viewpoint in regard to Bios differs somewhat from that of Miller.³ Dr. Miller prefers to assume that Wildier's bios is a complex composed of at least two factors, each of which in pure form will show little yeast growth-stimulatory effect but when combined will give the marked stimulation of that factor. Our own viewpoint has led us to believe that the bios effect of Wildier is the sum of the individual effects of a series of substances, each of which will in pure form show some stimulation. We therefore considered our Bios 223 and our beta bios as bioses, not pieces of a bios.

During the past year Eastcott⁴ has supported Miller's view by carrying the fractionation of Lucas's⁵ Bios I fraction further and separating therefrom inosite. This inosite in her hands when combined with Lucas' Bios II concentrate produced marked stimulatory effect on yeast growth. In her view, therefore, inosite would appear to be a component of Wildier's bios.

We found evidence to support our own view by the electrodialysis of yeast autolysate and of a water solution of Bios 223 (we prefer at present to designate this product as alpha bios). In the case of the autolysate we obtained solutions at markedly different pH which were stimulatory of yeast growth when combined with sugar-salt culture media. There were two such regions in the autolysate dialysate, one at pH 3.7 and the other at pH 8. The water solution of Bios 223 gave us only one such concentration, viz, at pH 8. We believe the pH 3.7 concentrate to be the holder of what we now call beta bios. The actual beta bios we isolated was, however, obtained by manipulation of the Bios I concentrate of Lucas⁶ being separated from the baryta precipitate. Last year this product had been impossible to crystallize. It was very hygroscopic but fairly uniform in composition as isolated.

These earlier preparations showed a variable but small amount of nitrogen.

¹ W. H. Eddy, R. W. Kerr and R. R. Williams. *Jour. Amer. Chem. Soc.*, vol. 46, page 2846. 1924.

² R. W. Kerr. *Soc. Exp. Biol. and Med.*, vol. 25, page 344. 1928.

³ L. Miller. *Science*, vol. 54, page 197. 1924.

⁴ E. V. Eastcott. *Jour. Phys. Chem.*, vol. 32, page 1094. 1928.

⁵ G. H. W. Lucas. *Jour. Phys. Chem.*, vol. 28, page 1180. 1924.

⁶ G. H. W. Lucas. *Jour. Phys. Chem.*, vol. 28, page 1180. 1924.

During the present year we have succeeded in making an acetylated addition product from our hygroscopic beta bios that is crystalline. Fein Chemie obtained on this product the following analysis: Carbon, 49.00 and 48.98; Hydrogen, 5.69 and 5.74; Nitrogen, absent.

Analyses of hygroscopic beta bios

Analyst	Date	Product analysed	
		Carbon	Hydrogen
Sewag, Rockefeller Inst.	Jan. 1928	42.76 p. ct.	6.52 p. ct.
Sewag	Jan. 1928	42.58	6.42
Sewag	Jan. 1928	42.65	6.60
Fein Chemie, Tubingen	Jan. 1928	44.35	6.63
Fein Chemie	Jan. 1928	44.24	6.46
Fein Chemie, Tubingen	July 1928	43.45	6.85
Fein Chemie	July 1928	43.32	6.57

Using the Rast camphor method we obtained the following molecular weight determinations: 1,070, 1,440 and 1,380, average 1,297. The crystals melted at 154° C. The crystals were themselves inactive but when the acetyl groups were split off by hydrolysis, the residue showed the same order of activity as the hygroscopic beta bios before acetylation.

Since Eastcott obtained her inosite by purifying Lucas' Bios I fraction and our beta-bios came from our fractionation of the same concentrate, we have attempted to discover what if any relationship exists between these two substances. We first attempted to verify Eastcott's claims that inosite supplements the Bios II concentrate in the stimulation of yeast growth. Using four different pure strains of yeast, a concentrate of Bios II prepared from mushrooms, as directed by Eastcott, and inosite, both as purchased and six times recrystallized, we have to date been unable to duplicate her results. Inosite with our concentrate and yeasts not only does not enhance the effect of the Bios II concentrate but actually inhibits it somewhat. On the other hand our beta bios definitely enhances the effect of the Bios II concentrate.

We then submitted our beta bios to Eastcott's drastic hydrolysis with HCl. We got the charring effect noted by her. From the residue after hydrolysis of 2 grams of beta-bios we recovered 140 milligrams of pure inosite. Inosite, therefore, seems to be a chemical component of our beta bios. How much it contains quantitatively was impossible to estimate from this hydrolysis owing to the great destruction of organic matter in the operation.

We are at present in conference with the Toronto workers and are endeavoring to arrive at the explanation of these results. We prefer to defer attempt at interpretation until a later period, and merely report these findings as observations and report of progress in the bios work.

VITAMIN C

In 1926 Wolbach and Howe¹ advanced an interesting theory as to the site and method of action of vitamin C. In their words:

"We therefore advance the theory that the failure of cells to produce intercellular substance in scorbutus is due to the absence of an agent common to all supporting tissues which is responsible for the setting or jelling of a liquid product."

They demonstrated that the setting of the intercellular substance produced by odontoblasts and known as dentine could be delayed or advanced by the deficiency or abundance of vitamin C in the diets of experimental animals. Höjer² suggested the use of tooth sections as specific means of measuring the antiscorbutic potency of foods, and in 1928 Goettsch and Key³ reported a critique of Höjer's method.

During the past year we have, with the aid of Dr. Dalldorf of the Department of Pathology of the New York Hospital, made detailed study of the response of tooth structure to variations in dosages of antiscorbutic with a view to both elaborating a simpler and less time-consuming test for vitamin C potency and also to obtain if possible confirmation of the work of Wolbach, Howe and Höjer. The details of our findings will be reported in detail elsewhere but we may note here that we find the teeth particularly suitable for such tests, responsive to very slight variations in dietary antiscorbutics and hence suitable for vitamin C test procedure, and that the response is apparently practically if not completely independent of the amount of vitamin D in the diet.

In concluding this report we wish to acknowledge the very great contributions to the success of our year's work made possible by the devotion of Messrs. Waterman and Gurin and also the contributory work of the laboratory staff in the multitude of effort necessary to the preparation of diets, animal tending, etc., incident to our tests.

¹ S. B. Wolbach and P. R. Howe. *Arch. Path. and Lab. Med.*, vol. 1, page 1. 1926.

² A. Höjer. *Acta Paediatrica*, 3 suppl., 1924; and *Brit. Jour. Exper. Path.*, vol. 7, page 356. 1926.

³ M. Goettsch and K. M. Key. *Quart. Jour. Pharmacy and Allied Sciences*, vol. 1, page 168. 1928.

PALÆOGRAPHY

Lowe, E. A., Oxford, England. *Associate in palæography.* (For previous reports see Year Books Nos. 9-16, 19-27.)

Palæographers are agreed that the day of the collection of miscellaneous facsimiles is past. The important task now confronting them is the investigation of special types and of individual centers. Such a study of a type that flourished for five centuries in a clearly defined region was published by the writer in 1914 under the title *The Beneventan Script*—a history of the South Italian minuscule. Its companion, *Scriptura Beneventana*, containing one hundred folio plates providing the illustrative material, was unfortunately interrupted by the war. Thanks to the generous support of the Institution it was possible gradually to re-examine the manuscripts described in the plates (92 in number, preserved in 19 different libraries in 7 countries). This work has now passed through its final stage, everything has been seen through the press and the two volumes will be out before this report is printed.

In the autumn of 1928, six weeks were spent in Italy working in the libraries of Monte Cassino, Naples, Rome and Florence. It is hard to be sufficiently grateful for the extraordinary facilities enjoyed at Monte Cassino, Rome and Naples; but special thanks are due to the Librarian of the Abbey of the Santissima Trinità of Cava, Dom Leone Cerasoli, and to the Librarian of Monte Cassino, Dom Mauro Inguanez, for their great kindness in arranging to have the Cava manuscripts sent to Monte Cassino so as to save the writer the loss of time involved in travel. In the spring of this year, six weeks were devoted to work upon manuscripts preserved in Brussels, Fulda, Würzburg, Bamberg, Munich and Paris. Special mention is due of the writer's obligation to the Librarians of Fulda and Bamberg, who spared themselves no trouble to render his brief visit as fruitful as possible. The writer wishes to take this opportunity to express his sense of appreciation of the enormous pains taken by the officials and the technical staff of the Clarendon Press in producing *Scriptura Beneventana*. During the winter, some time was devoted to making a study of the oldest extant manuscript of the Rule of St. Benedict. It happens to be written in uncial characters of the English type, and this gave the writer the opportunity to put together a list of the extant manuscripts and charters in English uncial. This was incorporated in an introduction to a small publication entitled *Regula S. Benedicti*, which Oxford University got out in honor of the fourteenth centenary of the foundation of Monte Cassino. Monte Cassino itself is celebrating the occasion by publishing a series of articles contributed by various scholars. The writer's article, *The Unique Manuscript of Tacitus' Histories* has already been seen through the press. Work has also been done during the year upon the *Index of Latin Facsimiles*. It should be ready for press by the end of the coming academic year.

PALÆONTOLOGY

Antevs, Ernst, American Museum of Natural History, New York, New York. *Preparation of new maps of the Pleistocene glaciations.*

As one of President H. F. Osborn's suggestions for the celebration of the centenary of the glacial theory by the American Association for the Advancement of Science at the New York meeting in December 1928, a series of maps illustrating the Pleistocene glaciations was, with the support of the Carnegie Institution of Washington, prepared by the writer. The maps are hemispherical, continental, and regional and intend to show in general features as well as in details the distribution and extent of the several glaciations, as far as this is possible at present. The maps are 21 in number and will appear (as text-figures) with text in the Bulletin of the Geological Society of America.

The drift borders in the Eastern United States of America have been generously supplied by Professor Frank Leverett, and the younger borders in Germany and Poland by Dr. Paul Woldstedt. Sincere thanks are also due to Dr. Chester A. Reeds for valuable advice and to Mr. George Pinkley for able assistance in the work.

The heterogeneous nature of the material bearing on the number and extent of the Pleistocene glaciations, and the diverging views in the different countries and of different geologists have made the present compilation a difficult task. The guiding principles have been to compile known data, to combine them in the most probable way, and to generalize as little as possible.

One map of the Northern Hemisphere shows the areas that were glaciated at one time or another and thus attempts to give a general idea of the location and extent of the former ice sheets and glaciers. Another similar map presents the last glaciation where its outline is known; for the rest it shows the extent of the once glaciated regions.

Maps of North America, Europe, Asia and South America give a better conception of the Pleistocene extent of ice in the different continents. Regional maps of parts of United States of America and Europe give in detail the borders of the successive ice sheets at their maximum, and also the mountain glaciations.

The text treats the Pleistocene glaciations on the entire globe, *i. e.*, also in parts where, for one reason or another, they are not shown on our maps. It treats and discusses the borders of ice sheets and ice caps, traces of former mountain glaciers, the age of the drift, the number of the glaciations distinguished and the correlation of the drift sheets from region to region and from continent to continent.

An extensive bibliography accompanies the text.

Merriam, John C., and Associates. *Continuation of palæontological researches.* (For previous reports see Year Books Nos. 20-27.)

During the past year, work of the group of investigators who have been engaged in conduct of comprehensive studies on history of life in the Pacific Coast region has been carried forward with as close adherence as possible to the original program. Extensive field studies have been undertaken by members of this group, including Dr. John P. Buwalda and Dr. R. W. Chaney, and important papers resulting from these continued investigations are in process of publication.

Dr. John P. Buwalda has continued his broadly conceived studies of the geological and palæontological history of the later epochs as represented in the formations of the Pacific Coast region. Especially significant are the studies by Dr. Buwalda which have resulted in the mapping of two areas in eastern Oregon which comprise together practically the whole of the section of the Pacific Coast region. Dr. Buwalda has also supported a plan to expand these researches so as to include a further area in the Blue Mountain region of eastern Oregon, which would extend the sequence of extraordinarily developed formations through the Mesozoic and Paleozoic. Furtherance of these studies would furnish an extraordinary geological section with an exceptional representation of life history. The studies of this field in the history of life have been continued in the main by Dr. Earl H. Packard of the University of Oregon. The results of Dr. Packard's work will be epoch-making when his materials have been finally assembled.

In association with Dr. Buwalda and others, Mr. Merriam has been concerned with development of many of the special problems in geology and palæontology, and with development of a comprehensive review of the detailed studies carried on through the past three decades in the fields of special work now being conducted by Dr. Buwalda, Dr. Stock, Dr. Chaney and Mr. Merriam.

In connection with the general interpretation of the geological and palæontological sequence, special attention has been given by Mr. Merriam and Dr. Buwalda to an effort designed to bring the results of researches in geology and palæontology of the outstanding areas in western North America to the highest attainable use for the advancement and stimulation of research and for educational purposes. In the eastern Oregon region, where Dr. Buwalda's studies have been carried on, plans are under way which it is hoped will bring about setting aside of some of the classic geological and palæontological sections for intensive use in research and education. In connection with the program of National Parks and National Forests a further study has been undertaken which will, it is believed, ultimately have great influence in the stimulation and development of research along lines which have been laid down in the fundamental studies in this field in the course of the past thirty years.

The following reports have been submitted, relating to the work of Dr. Buwalda, Dr. Kellogg and Dr. Stock.

Investigations by John P. Buwalda

The geologic mapping of the Picture Gorge and Mitchell quadrangles in the John Day region of eastern Oregon having been essentially completed, but little additional field work was done in this region during the Summer

of 1928. A brief visit was made to the district in connection with other duties and certain additional observations secured regarding the physiographic history.

Mapping and study of the marine and landlaid formations in the Tejon Pass region and in the western end of the Mohave Desert in southern California was advanced during the Winter and Spring of 1928-29. The relations are complicated, due to the number of formations present, their strong deformations by folding and faulting, and the shearing of the area into slices by movements along the San Andreas fault, which crosses the area. The study promises to yield important information regarding the tectonic history and relations of the Coast Ranges, the Sierra Nevada, and the Mohave Desert, these three provinces meeting at the Tejon Pass plexus.

The mapping of the Indio Hills, an area about 20 miles by 3 miles in dimensions, lying within the Salton depression in southern California and furnishing clues to the Tertiary history of the Colorado Desert region, was carried forward in collaboration with Mr. W. Layton Stanton. It has been found that the upper part of the Hills block consists of several thousand feet of terrestrial strata elsewhere defined as the Indio formation. The Carrizo formation, marine in origin, underlies the Indio and represents the last record of marine invasion in the area. The San Andreas fault is found to cut obliquely across the northwestern end of the Hills and bounds the block on the southwest side instead of on the northeast as has been supposed heretofore. The materials of the Indio formation yield considerable data regarding their origin and the physiographic conditions at the time of their deposition in Neocene time. The folded and faulted structure of the hills is apparently related to movement and forces active along the bordering San Andreas fault.

The Mecca Hills, an area lying to the southeast and of somewhat similar size and history, are being studied in collaboration with Mr. Hampton Smith. While considerable mapping has been done and data collected, this study has not progressed to the stage of safe generalization regarding structure and history.

Report of Researches by Remington Kellogg

During the past season the following investigations have been in progress:

(1) In carrying out the project for "A study of the evolutionary history of the cetaceans," plans have been made for intensive field work in the Jackson formation of Alabama and Mississippi. Previous field work in the North American Upper Eocene formations has resulted in the acquisition of some very promising material. Unfortunately most of the specimens were prepared by persons inexperienced in such matters. The scientific value of many of the specimens heretofore collected has been reduced or even destroyed by the lack of experience on the part of the collector. Our actual knowledge of the zeuglodonts that occur in the Jackson fauna is rather meager. Although much of the material previously collected is unsatisfactory, it does indicate the kind of specimens that may be made available for study by a skilled preparator. Study of available North American material has brought to light some very interesting anatomical details. In so far as our present knowledge goes the zeuglodonts are much older than the true whales and porpoises, and it is expected that some addi-

tional data in regard to the relationships of these groups will be made available by this study.

As a further step in prosecuting comparative studies on the faunas of Atlantic and Pacific formations, the writer visited California in May and June 1929. While making this trip the opportunity was taken to stop off at several points enroute for the purpose of examining specimens in other collections. At the Field Museum of Natural History in Chicago, the skull and mandibles of the South American Miocene Patagonian whalebone whale (*Cetotheriopsis moreni*) were studied. A well-preserved skull of one of the Miocene Temblor cetotheres was examined at the California Institute of Technology at Pasadena, and attention was called to the importance of certain fossil material from a nearby Eocene formation. At Los Angeles, the rostrum and fore part of the skull of an extinct porpoise seemingly allied to the living false killer porpoise (*Pseudorca*) was of particular interest. The other material consisted of skeletal parts of Monterey cetotheres. On arriving at Santa Barbara, attention was at once directed to an inspection of the large collection of fossils, many of which were well-preserved skeletal material of whales, in the garden of Dr. A. P. Ousdal. Included in this collection were the skulls of apparently two species of small cetotheres as well as vertebræ and other skeletal elements of larger cetaceans. The beach where this collection was obtained was visited and the sites where the specimens were found were noted. The Santa Barbara Museum of Natural History has a well-preserved skull, the fore part of the vertebral column, and part of the fore limb of one of the small Monterey cetotheres. The recently received fossil cetacean material in the California Academy of Sciences was examined, but nothing of especial interest was noted. A partial skeleton of a large fossil whalebone whale has been received by the Museum of Paleontology of the University of California. Arrangements were made with Dr. David Starr Jordan to have two partial skeletons of fossil porpoises preserved in diatomaceous earth forwarded to Washington for study.

Search for cetacean material in the Calvert Miocene formation of Maryland has been continued and additional material has been secured.

Report of Researches by Chester Stock

The palæontological field operations conducted during 1928-29 were again made in cooperation with the California Institute of Technology. During the summer of 1928 the party consisted of Chester Stock, E. L. Furlong, Charles L. Gazin, L. C. Hookway and E. R. Inglee.

Results accomplished in the field investigations are as follows:

(1) Further collecting of Tertiary mammals in the middle John Day beds exposed along the John Day River north of Picture Gorge, north central Oregon. Vertebrate remains were also secured from the Rattlesnake Pliocene and Mascall Miocene deposits exposed south of the Gorge.

(2) A further investigation of the Pliocene beds near Harper, Malheur County, Oregon, and a collection of additional vertebrate remains from the e deposits.

(3) Discovery of Miocene mammals in white tuffaceous sandstones and nodular tuffs at a locality approximately 28 miles west of Harper in the drainage basin of the Malheur River. The fauna includes merychippine

and anchitheriine horses, amphicyonine dogs and several species of rodents including mylagaulid and aplodont types. This assemblage is extremely interesting because of its geologic position and apparent similarity to the Middle Miocene faunas of the Mascall and Virgin Valley of the northern Great Basin Province. Moreover the constituents of the fauna would seem to indicate an environmental facies in agreement with the presumed physical history of the region during this stage of the Miocene. The geographic position of the deposits and fauna in a region situated between the Middle Miocene Mascall horizon of central Oregon and the Payette horizon of Idaho makes a critical determination of the age and relationships of the new fauna an important problem for further investigation.

(4) Discovery of a Miocene mammalian fauna in beds presumed to be the correlative of the Payette formation of Idaho and exposed in the basin of Sucker Creek, Malheur County, Oregon, was announced last year. Collecting over the deposits in 1928 has materially increased the fossil assemblage and emphasizes the possibility of relationship of the fauna to the Mascall and to the Virgin Valley assemblage of northwestern Nevada.

(5) Systematic collecting in Pleistocene and late Tertiary deposits along the Owyhee River near Rome, Malheur County, Oregon, has brought to light two faunal horizons of great importance in the interpretation of the later Cenozoic history of southeastern Oregon.

(7) Renewed search for Pliocene mammals in the Thousand Creek beds of northwestern Nevada yielded a relatively large collection, including more complete remains of the mastodon, horses and antelopes. *Hipparion leptode* Merriam is now known by very complete skull and skeletal material.

A preliminary statement of the occurrence of Pleistocene elephants on Santa Rosa Island, California, was published by Stock and Furlong, and a paper by Stock relating to the significance of abraded and weathered mammalian remains from Rancho La Brea has been accepted for publication.

Studies of the Rancho La Brea mammalian assemblage were advanced as follows:

(1) A comprehensive review of the osteology and odontology of the Pleistocene cats and the preparation of the necessary illustrative material for the memoir on the Felidæ have been nearly completed.

(2) Dr. R. L. Moodie has continued his studies of the incidence of disease among the sabre-tooth cats of the Rancho La Brea fauna.

The following papers have been prepared for publication:

Stock, Chester: Oreodons from the Sespe Deposits of South Mountain, Ventura County, California.

Furlong, Eustace L.: *Capromeryx minor* Taylor from the McKittrick Pleistocene, California.

Gazin, Charles Lewis: A Tertiary Vertebrate Fauna from the Upper Cuyama Drainage Basin, California.

Maxson, John H.: A Tertiary Mammalian Fauna from the Mint Canyon Formation of Southern California.

Stock, Chester: A census of the Pleistocene mammals of Rancho La Brea, based on the collections of the Los Angeles Museum, Jour. Mammal., accepted for publication.

Stoyanow, A. A., University of Arizona, Tucson, Arizona. *Assistance in completion of manuscript on upper palæozoic invertebrate fossil material.*

Dr. Stoyanow has been engaged in studies of Cambrian, Devonian and Mississippian formations of Arizona and their faunas. He has visited eastern museums in order to study certain collections and to obtain access to palæontological monographs not available in Arizona.

During the past year Dr. Stoyanow has prepared papers for publication on the following subjects:

1. The Cambrian formations in Southeastern Arizona and their Trilobite faunas.
2. The aspects of the Devonian in Arizona.
3. Observations on the Mississippian Corals of Arizona.

Mr. R. L. S. Heineman of the Arizona Bureau of Mines has assisted Dr. Stoyanow in preparing palæontological plates for his papers.

White, David, National Academy of Sciences, Washington, D. C. *Study of the fossil floras in the Grand Canyon, Arizona.* (For previous reports see Year Books Nos. 26, 27.)

The greater part of three weeks in June was spent in the examination of the Unkar group, the lower division of the Proterozoic, in search for further evidence of life in these very ancient rocks. Work was mainly confined to outcrops along or near Bright Angel Creek. Plans for an expedition into the Kwangunt and Nunkoweap region of the Chuar group, which lies above the Unkar, were postponed for the season on account of the restricted time available. Consequently no beds higher than those exposed along Bright Angel Creek between Ribbon Falls and the Union Pacific power plant were examined.

Obscure traces suggesting fucoids but possibly mechanical in origin were found near the base of the Shinumo quartzite. Markings difficult to explain except as impressions of algal thalli were found abundantly in silty shales near the top of the Hakatai shale. Lower in the section, two thin zones of dark red beds, transitional from the Hakatai into the Bass limestone, revealed several forms of small, slightly crooked, fusiform remains, which appear fairly certainly organic. The question as to the kind of organisms that were responsible for these remains may long rest in doubt. It is possible that we have here to do with the work of bacteria related to *Crenothrix*. A thin greenish-blue limestone lying between red shales and sandstones below the top of the Bass limestone presents somewhat definitely figured forms that appear safely attributable to lime incrustated micro-algæ. Several forms of limestone growth, probably of algal origin, were found at different levels in the Bass limestone in the walls of the Grand Canyon or in the syncline along Bright Angel Creek. None of the specimens collected this year have been studied.

Interesting impressions of salt crystals over an inch in diameter were found in large numbers in a thin lavender-purple bed in the upper part of the Bass limestone west of Phantom Ranch. Impressions of smaller crystals have been found at other levels. The salts, deposited by evaporation of shallow pools of water spread over the hematite-red silty muds, evidently went into solution again when the area was overswept with fresher water loaded with silt.

The composition and depositional phenomena of the Bass limestone are viewed as indicating the presence of a very shallow epicontinental sea in this region of Proterozoic sedimentation; also a relatively dry climate. Ripple marks and mud cracks are not uncommon at several levels, especially near the base of the Hakatai shale, as has been noted by Noble in the Shinumo quadrangle.

The study of the Supai formation and of the Hermit shale was limited by lack of time. Very little new plant material was found. Plant remains occurring near the base of the Supai were evidently transported and considerably macerated before burial. An additional species of *Walchia* was found east of the Yaki Trail in beds within 25 feet of the base of the Supai (lower Permian) which is here marked by a residual conglomerate on the uneven surface of the Redwall limestone.

A deposit containing *Walchia gracillima* in great abundance was found about 200 yards east of Cedar Flat and large numbers of a *Supaia*, nearest related to *S. merriami*, are present at one point nearly midway on the Dripping Springs Trail in the Hermit basin. These localities forcibly illustrate the frequent occurrence of but a single form or the remarkable predominance of a single plant species at any one point in the Hermit basin.

Additional specimens were gathered for exhibition or illustration at the Yavapai Observation station.

In Glacier National Park, which was visited for three days on the journey eastward, portions of the Algonkian (Proterozoic) were searched for fossils. Here several forms of lime deposit that appear to have been due to algæ were found in thin limestones along the road on the west side of the Continental Divide near Logan Pass.

Also, in the Altyn limestone, the basal formation of the Proterozoic of this region, beds were discovered about a mile below Lake McDermott, which carry a profusion of forms that strikingly resemble, if they do not actually represent, the remains of fragile thalli of algæ. These fragments, which seem to be marked by very thin carbonaceous residues, are fractured as though coated by exceedingly thin incrustations. They lie scattered generally parallel to the bedding planes, but with little or no directional orientation. They are comparable to the impressions collected by Walcott in the Belt limestone group of northern Montana, and included by him in his genus *Beltina*.

Several beds of the Newlyn limestone are notable for the presence of great numbers, as though in widespread colonies or reefs, of concentrically proliferous ascending growths, the form and microstructure of which very forcibly suggest the work of lime scale-forming algæ.

A report on the flora of the Hermit shale, Grand Canyon, Arizona, soon to be issued as Publication No. 405 of the Institution, is now in progress.

PHILOSOPHY

Heidel, W. A., Wesleyan University, Middletown, Connecticut. *Studies on a comprehensive and critical history of early Greek thought.*

The earlier part of the year was devoted largely to seeing my book, *The Day of Yahweh*, through the press, from which it issued in April. Meanwhile, however, I was revising and completing my collection of notes for a number of extended studies in the field of Greek scientific and philosophic thought, especially the two which I hope next to finish for publication, to wit: *The Beginnings of Science*, dealing with the concept and ideal and the methods of science, rather than the particular additions to the sum of knowledge, and *Egypt in the Greek Tradition*, which will throw a strong and surprising light on early Greek thought, because Egypt occupied a singular place in the thought of the early Greeks, seeming to them to offer not only the absolute scale, in its immemorial civilization, for a revision of their traditional chronology and thus to give the frame for universal history, but also the ideal field for geological study and the investigation of the origin of the inhabitable earth and the development of life upon it, Egypt being regarded as the cradle of the human race.

In this work I have been greatly helped by my efficient assistant, Miss Elsie Spoerl (A.B., Radcliffe, 1928).

PHYSICS

Compton, K. T., Princeton University, Princeton, New Jersey. *Investigations in the field of spectroscopy, to be conducted at Princeton University.*

Funds have been provided by the Carnegie Corporation of New York to the Carnegie Institution of Washington in support of this project. The first and chief objective is the construction and use of a large vacuum spectrograph for extreme ultra-violet spectroscopy. The plans of this spectrograph have been completed and it is in progress of construction in the Palmer Laboratory Shop. The design permits the use of a very fine diffraction grating ruled especially for this work by Professor R. W. Wood, and it has several unique features. One of these is the arrangement to photograph the spectrum from the shortest available wave-lengths clear up to the region which can be photographed with a quartz instrument in air, all recorded simultaneously on a single photographic plate with an expected resolving power considerably greater than that which has heretofore been used in at least the shorter wave-length region. A second feature is the employment of a set of magnetic controls whereby the camera can be operated from the outside without danger of introducing air. The instrument is constructed entirely of brass with the exception of an I-beam stand and weighs approximately two tons. Nearly all the parts have now been constructed and the instrument is in process of assembling. It is hoped that it will be ready for testing and for attaching the auxiliary glass system for handling gases, etc., by the time the University opens in the fall.

The materials purchased for this instrument have been paid for out of the grant and a first-class mechanic has been hired to take charge of the machine work. He has had the assistance of from one to three other mechanics of our laboratory staff during various stages of construction.

There are three articles now in course of publication whose authors have received more or less assistance from the grant of the Carnegie Institution during the course of the respective investigations. These comprise two articles in spectroscopy by Professor A. G. Shenstone and Dr. J. E. Mack respectively, and also a paper by Mr. S. A. Korff on the opacity of sodium vapor in the neighborhood of its absorption lines. The first two authors mentioned have been aided through use of a computing machine and the latter author by use of a specially constructed interferometer, both of which instruments have been in part made possible by the grant of the Carnegie Institution.

Millikan, R. A., Norman Bridge Laboratory of Physics, California Institute of Technology, Pasadena. *Research Associate in Physics.* (For previous reports see Year Books Nos. 22-27.)

The subjoined forty-nine major papers that have been published from the Norman Bridge Laboratory from July 1, 1928, to July 1, 1929, as a result of the support of the Carnegie Corporation of New York of the special research program in that Laboratory on atomic structure and the nature of radiation, may be classified under ten major heads and their significance very briefly touched upon as follows:

1. There are nine papers of general cosmic significance, namely, Nos. 1, 4, 6, 8, 11, 25, 32, 33 and 38. These are notable papers by Tolman and Zwicky on the thermodynamics of the universe, by Millikan and Cameron on the origin of cosmic rays, and by Bowen on the nature of the stellar nebulae.

2. There are six photoelectric papers of importance, namely, Nos. 14, 16, 17, 24, 29 and 44 that are by DuBridge, Warner and Goetz. Dr. Goetz's papers are particularly notable, since he has for the first time solved the difficult problem of measuring the change in the value of the long wavelength limit in passing from the liquid to the solid state or from one allotropic modification of the solid state to another. This has involved measuring accurately the smallest photoelectric currents yet measured, namely 10^{-18} amperes.

3. There are five exceedingly important papers on the Raman effect, namely, 22, 27, 37, 39 and 48. In these papers Rasetti has during the past year pushed forward knowledge of this field in an altogether extraordinary way, verifying significant predictions of the new wave mechanics.

4. There are seven major spectroscopic papers, namely, Nos. 5, 9, 18, 31, 35, 40 and 43 by Bowen, Ingram, Houston, Frayne, Muskat and Epstein, notable among them being those establishing a relation between intensity and pressure as demonstrated by Bowen's theory of "forbidden jumps."

5. There are five papers on the Compton effect and X-rays, namely, Nos. 13, 15, 41, 45 and 49, those by DuMond being especially notable because they seem to present the first direct evidence for the "Fermi distribution" of electron velocities in metals.

6. Zwicky's and Lauritsen's papers Nos. 26, 42 and 19 represent new and notable contributions to crystal structure and to vacuum technic.

7. There are two papers, Nos. 2 and 28, on the passage of ions through atoms, that by Sutton being of especial significance because it demonstrates that positive ions are of very much longer free paths than had heretofore been thought possible.

8. There are two papers which throw new light on the nature of magnetism, Nos. 3 and 47.

9. There are two papers, Nos. 30 and 34, one theoretical and one experimental, which throw new light on the nature of field currents.

10. There are eight theoretical papers, Nos. 7, 10, 12, 20, 31, 36, 40 and 41 by Oppenheimer, Sommerfeld, Houston, Epstein and Cassen, on the new wave mechanics and allied fields.

1. On the Thermodynamic Equilibrium in the Universe. F. Zwicky, *Proc. Nat. Acad. Sci.*, vol. 14, 592-597 (1928).
2. Angular Scattering of Electrons in Hydrogen and Helium. Gaylord P. Harnwell, *Proc. Nat. Acad. Sci.*, vol. 14, 564-569 (1928).
3. Evidence Obtained by X-ray Analysis of Films of Iron in Magnetic Fields as to the Ultimate Nature of Magnetism. T. D. Yensen, *Phys. Rev.*, vol. 32, 114-123 (1928).
4. Evidence that the Cosmic Rays Originate in Interstellar Space. Robert A. Millikan and G. Harvey Cameron, *Proc. Nat. Acad. Sci.*, vol. 14, 637-641 (1928).
5. The Spectrum of Sulphur, SII. S. B. Ingram, *Phys. Rev.*, vol. 32, 172-178 (1928).

6. Further Remarks on the Second Law of Thermodynamics in General Relativity. Richard C. Tolman, *Proc. Nat. Acad. Sci.*, vol. 14, 701-706 (1928).
7. On the Quantum Theory of Electronic Impacts. J. R. Oppenheimer, *Phys. Rev.*, vol. 32, 361-376 (1928).
8. Available Energy. Robert A. Millikan, *Science*, vol. 68, 279-284 (1928).
9. Forbidden Lines in the Flash Spectrum. I. S. Bowen and R. H. Mensel, *Proc. Astro. Soc. Pacific*, vol. 40, 332-339 (1928).
10. On the Distribution Law in Locally Rapidly Fluctuating Fields which are Steady When Averaged Over a Sufficient Time Interval. Benedict Cassen, *Proc. Nat. Acad. Sci.*, vol. 14, 763-766 (1928).
11. Origin of the Cosmic Rays. R. A. Millikan and G. H. Cameron, *Phys. Rev.*, vol. 32, 533-557 (1928).
12. Spectral Intensities of Radiation from Non-Harmonic and Aperiodic Systems. Benedict Cassen, *Proc. Nat. Acad. Sci.*, vol. 14, 880-882 (1928).
13. The Structure of the Compton Shifted Line. Jesse W. M. DuMond, *Proc. Nat. Acad. Sci.*, vol. 14, 875-878 (1928).
14. Systematic Variations of the Constant A in Thermionic Emission. Lee A. DuBridge, *Proc. Nat. Acad. Sci.*, vol. 14, 788-793 (1928).
15. Experimental Confirmation for Sommerfeld-Fermi-Dirac Degenerate Gas Theory of Conduction Electrons. Jesse W. M. DuMond, *Science*, vol. LXVIII, 452 (1928).
16. Thermionic Emission from Clean Platinum. Lee A. DuBridge, *Phys. Rev.*, vol. 32, 961-966 (1928).
17. Critical Photoelectric Potential of Clean Mercury and the Influence of Gases and of the Circulation of the Mercury upon it. Wayne B. Hales, *Phys. Rev.*, vol. 32, 950-960 (1928).
18. Intensity Measurements in the Helium Spectrum. Clarence Hodges and W. C. Michels, *Phys. Rev.*, vol. 32, 913-917 (1928).
19. A New High Potential X-ray Tube. C. C. Lauritsen and R. D. Bennett, *Phys. Rev.*, vol. 32, 850-857 (1928).
20. On the Symmetry of Protonic Wave Functions. Benedict Cassen, *Proc. Nat. Acad. Sci.*, vol. 15, 29-31 (1929).
21. The Relation of Science to Industry. Robert A. Millikan, *Science*, vol. LXIX, 27-31 (1929).
22. Raman Effect in Gases. F. Rasetti, *Nature*, vol. 123, 205 (1929).
23. Transmutation of Elements, L. Thomassen, *Phys. Rev.*, vol. 33, 229-238 (1929).
24. Der Photoelektrische Effekt bei Zustandsänderungen der Kathode. Alexander Goetz, *Zeit. f. Phys.*, vol. 53, 494-525 (1929).
25. The Presence of Sulphur in the Gaseous Nebulae. I. S. Bowen, *Nature*, vol. 123, 450 (1929).
26. On the Imperfections of Crystals. F. Zwicky, *Proc. Nat. Acad. Sci.*, vol. 15, 253-259 (1929).
27. On the Raman Effect in Diatomic Gases. F. Rasetti, *Proc. Nat. Acad. Sci.*, vol. 15, 234-237 (1929).
28. Ionization of Gases by Positive Ions. Richard M. Sutton, *Phys. Rev.*, vol. 33, 364-372 (1929).
29. The Photoelectric Effect of Molten Tin and Two of Its Allotropic Modifications. Alexander Goetz, *Phys. Rev.*, vol. 33, 373-385 (1929).
30. Temperature Dependence of Electron Emission under High Fields. Wm. V. Houston, *Phys. Rev.*, vol. 33, 361-363 (1929).

31. Some Relationships between Singlets and Triplets in the Spectra of Two Electron Systems. Wm. V. Houston, *Phys. Rev.*, vol. 33, 297-304 (1929).
32. Is there Argon in the Corona? H. N. Russel and I. S. Bowen, *Astro. Jour.*, vol. LXIX, 196-208 (1929).
33. On the Possible Line Elements for the Universe. Richard C. Tolman, *Proc. Nat. Acad. Sci.*, vol. 15, 297-304 (1929).
34. Dependence of Electron Emission from Metals upon Field Strengths and Temperatures. Robert A. Millikan and C. C. Lauritsen, *Phys. Rev.*, vol. 33, 598-604 (1929).
35. Variation in the Intensities of Mercury Spectrum Lines with Pressure of the Vapor. John G. Frayne and Carol G. Montgomery, *Phys. Rev.*, vol. 33, 549-552 (1929).
36. Zur Theorie des Radiometers. Paul S. Epstein, *Zeit. f. Phys.*, vol. 54, 537-563 (1929).
37. Selection Rules in the Raman Effect. F. Rasetti, *Nature*, vol. 123, 757-759 (1929).
38. On the Astronomical Implications of the DeSitter Line Element for the Universe. Richard C. Tolman, *Astro. Jour.*, vol. LXIX, 245-274 (1929).
39. On a Fluorescence Spectrum of Oxygen. F. Rasetti, *Proc. Nat. Acad. Sci.*, vol. 15, 411-414 (1929).
40. On the Continuous Spectrum of Hydrogen Atom. Paul S. Epstein and Morris Muskat, *Proc. Nat. Acad. Sci.*, vol. 15, 405-411 (1929).
41. About the Production of the Continuous X-ray Spectrum. A. Sommerfeld, *Proc. Nat. Acad. Sci.*, vol. 15, 393-400 (1929).
42. On the Internal Pressure of Strong Electrolytes. H. M. Evjen and F. Zwicky, *Phys. Rev.*, vol. 33, 860-868 (1929).
43. Pure Rotation Spectrum of Ammonia. Richard M. Badger and C. Hawley Cartwright, *Phys. Rev.*, vol. 33, 692-700 (1929).
44. Variation of Photoelectric Effect with Temperature and Determination of the Long Wave-Length Limit for Tungsten. A. H. Warner, *Phys. Rev.*, vol. 33, 815-818 (1929).
45. Compton Modified Line Structure and Its Relation to the Electron Theory of Solid Bodies. Jesse W. M. DuMond, *Phys. Rev.*, vol. 33, 643-658 (1929).
46. Michelson's Economic Value. R. A. Millikan, *Science*, LXIX, 481-485 (1929).
47. Magnetic Properties of Isolated Atoms of Cobalt. F. W. Constant, *Nature*, vol. 123, 943 (1929).
48. On the Raman Effect in Diatomic Gases. II. F. Rasetti, *Proc. Nat. Acad. Sci.*, vol. 15, 515-519 (1929).
49. The Valence of Sulfur in Dithionates. Ralph E. Winger and Don M. Yost, *Proc. Nat. Acad. Sci.*, vol. 15, 462-464 (1929).

Committee on the Study of the Surface Features of the Moon. *Progress report for the period July 1928 to June 1929.* (For previous report see Year Book No. 27.)

In the attack on the problems presented by the surface features of the moon the committee is seeking to ascertain (a) the nature of the materials exposed at the surface of the moon; (b) their behavior under lunar surface conditions; (c) with this information at hand to proceed to the classification of the surface features and to the analysis of the several hypotheses that have been suggested to account for them.

The first step in the program is essentially a comparative study of sunlight and moonlight for the purpose of determining the changes that are produced in the sun's rays on reflection at different points on the moon's surface. A comparison of these changes with those produced by terrestrial materials under similar conditions leads to a grouping of the materials and thus to a fairly definite identification of lunar surface substances.

QUARTZ SPECTROGRAPH WITH DOUBLE IMAGE PRISM

The changes produced in the sun's rays on reflection are of two kinds, namely, selective reflection and polarization. Apparatus and methods have been developed for measuring these effects. A new quartz spectrograph attachment equipped with a double image quartz prism has been constructed and is now in use by Dr. Adams and Dr. Pettit. With it the relative intensity of illumination of a given point on the moon's surface is determined for all wave-lengths from the ultra violet through the visible spectrum to the near infra red; on insertion of the quartz prism the intensity of illumination at the given point for vibrations in the plane of incidence and for vibrations normal to the plane of incidence are obtained simultaneously in separate spectra. From the differences in intensities of these spectra the amount of polarized light in the reflected beam can be ascertained for any wave-length in the spectrum. Similar studies on terrestrial materials have been started and, when finished, will furnish the basis for comparisons between substances found on the earth and those on the moon.

LUNAR RADIATION

A reduction of the measurements of lunar radiation made by Dr. Pettit and Dr. Nicholson since 1922 has been completed. Drift curves across the disk at full moon with and without glass screen give the distribution of planetary heat and reflected light. These show that the distribution follows the empirical law, $E = a \cdot \cos^{3/2} \vartheta$, where ϑ is the angular distance of a point from the subsolar point; the theoretical distribution of planetary heat over an illuminated sphere is, however, $E = a \cdot \cos \vartheta$. This difference between observation and theory may be explained by the rough lunar surface. The distribution of reflected light follows Lambert's cosine law in general; the maria are only three-fourths as bright as the mountainous regions in the middle of the disk.

The radiometric magnitude of planetary heat from the subsolar point at full moon is $+1.39$ per square second corresponding to a temperature of 402°K . At quarter phase, on the other hand it is $+1.92$ corresponding to 355°K . From this it would seem that the rough surface has a directional action on the planetary heat radiated by it. The reciprocity principle indicates that it is the average energy vector of the emitted radiation which must be compared with that received from the sun. The complete distribution function is being determined by measurements at various phases, but, if we assume that it is elliptical, the mean radiometric magnitude of planetary heat per square second at the sub-solar point is $+1.74$, corresponding to 370°K .

The whole reflected light determined with the cover-glass and water-cell at full moon and at quarter phase is $0.36 \text{ cal. cm.}^{-2} \text{ min.}^{-1}$ and the conducted heat determined at the eclipse of June 14, 1927, was $0.1 \text{ cal. cm.}^{-2}$

min.⁻¹. Taking the solar constant at 1.95 cal. cm.⁻² min.⁻¹ this gives a temperature of 367° K. for the sub-solar point corresponding to a radiometric magnitude of +1.76 per square second of planetary heat which is in good agreement with the radiometric measurements indicated above.

The radiometric magnitude of the whole reflected light from the full moon is -13.1 and the radiometric magnitude of the whole radiation is -14.6. The radiometric albedo of the moon is 0.078, while for visual light the albedo is 0.073.

The radiometric magnitude of a square second of planetary heat which reaches us from celestial objects of various temperatures has been computed, and from this computation it appears that the lowest temperature which can be detected with certainty is in the neighborhood of 70° K; temperatures below 100° K can be measured only with great difficulty.

A reduction of the measurements made on a point 0.05 radius from the south limb at the lunar eclipse of June 14, 1927, shows that, if as much heat must be restored to the moon as was given up by it during the eclipse in order to restore the stable state, about 0.1 cal. cm.⁻² min.⁻¹ must have been conducted into it at the beginning of the eclipse.

From the data obtained at this eclipse and the observed rapid rate of cooling of the lunar surface Dr. Epstein has shown that the actual surface layer, which absorbs and radiates heat, is very thin, in other words that the substances exposed at the moon's surface are good heat insulators. Theoretically the decrease of temperature for the initial phase of the eclipse should follow the law $\Delta T = -4At^{3/2}/3t_0 (\pi k \rho c)^{1/2}$; A, denotes the insulation in the beginning; t, the time counted from a moment a few minutes after the setting in of the eclipse; t₀, the duration of the penumbra stage; k, the heat conductivity; ρ the density; c, the specific heat of the material at the moon's surface. Comparison with Pettit and Nicholson's curve gives for $(k \rho c)^{-1/2}$ a value of about 120. For terrestrial materials this coefficient has the values: granite 16, basalt 24, quartz sand 58, cellite 90, pumice stone 100 to 150. The observed value 120 corresponds to that obtained for volcanic ash or pumice, or other highly porous substances.

LUNAR RADIATION DURING THE LUNAR ECLIPSE OF NOV. 26, 1928

Radiation from the moon during this eclipse was examined by Dr. Pettit with a special equipment adapted to the Snow telescope on Mount Wilson. A 27-inch mirror of 67 inches focal length was used. An automatic device registered, at intervals of 20 seconds, the total radiation and that transmitted by the cover-glass screen and printed a time scale on the photographic plate. Radiation from the center of the disk was measured throughout the eclipse. The results agree substantially with those obtained from a point located 0.05 radius from the south limb at the eclipse of June 14, 1927; but they are more detailed. The same equipment is being used to determine the distribution of planetary heat and reflected light over the hemisphere about the sub-solar point.

REFLECTION OF LIGHT BY TERRESTRIAL MATERIALS

Measurements of the intensities of light reflected by 100 different terrestrial materials are being made by F. E. Wright and J. England at the

Geophysical Laboratory. For this purpose a vacuum thermo-element with a fused quartz window is being used. Intensity measurements for different angles between incident and reflected rays, for different regions of the spectrum and for light vibrating in and normal to the plane of incidence are taken. Similar observations on the light reflected by the moon are planned for the purpose of comparison and identification of lunar surface substances.

LUNAR OBSERVATIONS

Direct photographic observations of the moon have included many photographs made by Dr. F. G. Pease through different color filters of glass of known spectral transmissions. Six negatives of the earth-lit moon were obtained by Dr. Duncan with the 100-inch reflector for the use of Professor W. H. Pickering.

A careful study by Dr. Pease of the negatives of the moon taken during the past decade has failed to reveal any changes in its surface features. Visual observations of the moon's surface with the aid of the 100-inch reflector have been made by Drs. Buwalda, Day, Pease and Wright. A physiographic study and classification of the lunar surface features is being made by Dr. Buwalda.

LUNAR PHOTOGRAPHIC MAP

Detailed studies of the surface features of the moon require an accurate base map. A map for this purpose is being constructed from the series of excellent photographs of the moon taken by F. G. Pease with the 60- and 100-inch reflectors. The photographs are transformed photographically so that in each photograph the moon is viewed along the same standard line of sight; this transformation is necessary if the relative positions of any two given points are to be the same in the different photographs. Because of libration the line of sight to the moon changes from day to day within certain limits; but for map making purposes the moon must be viewed in each photograph along the standard line of sight. The transformation of the photographs is not an easy matter, but methods for the purpose have been devised and the necessary apparatus has been assembled. A special projection chart has been prepared, by means of which the standard line of sight on each negative can be determined and also the angle it includes with the line of sight of the negative.

It is believed that the accumulation of data of measurement by methods in which the subjective element has been eliminated so far as possible is the necessary first step to any satisfactory study of the moon's surface features.

W. S. ADAMS,
J. P. BUWALDA,
A. L. DAY,
P. S. EPSTEIN,
F. G. PEASE,
H. N. RUSSELL,
F. E. WRIGHT (*Chairman*).

PHYSIOLOGY

Russell, G. Oscar, Ohio State University, Columbus, Ohio. *Physiological cause of voice quality in singing.*

The following report concerns studies undertaken by Dr. Russell with funds appropriated by the Carnegie Corporation of New York to the American Academy of Teachers of Singing for support of a scientific study of singing, said funds being payable through the Carnegie Institution of Washington.

Dr. Russell has had the cooperation of a number of agencies. The Electro Surgical Instrument Company, of Rochester, New York, rendered service without charge in extensive research work and in the manufacture of the fonofaryngoskop, prepared according to specifications and reported before the Chicago oto-laryngological section of the American Medical Association in April 1929. Physicians generally throughout the country have shown considerable interest, since this instrument makes possible the demonstration of pathological conditions in the larynx and lower throat to the patient himself, with simultaneous observation by the doctor and a large number of students (or relatives, if advisable) in the room. Many interesting facts in regard to physiological function in speech and voice have been discovered thereby. Some of these were reported in May 1929, in New York, in a paper before the Acoustical Society of America on the *Physiological Cause of Vowel and Voice Quality Differences*, which will be published in the proceedings of the Society.

The Research Laboratories of the Eastman Kodak Company have also cooperated freely and without charge. Mr. Tuttle and Mr. Morrison working under Dr. L. A. Jones, of the Physics Department, have devoted a great deal of time in this connection, but difficulty still exists in that aspect of the program. Lenses are required which are not available commercially and which would be rather expensive. It is quite essential that photographic evidence be had, and Dr. Russell hopes to obtain satisfactory lenses, and is continuing his efforts in this direction. A personal visit (financed under this grant) to various optical technicians abroad has resulted in the successful development of his speech-glotoskop. This piece of apparatus makes it possible to see for the first time and study the back throat, interior larynx, vocal cord function and well down into the trachea, without any impediment of speech or song. Even an S, T or NG, can be normally pronounced. This would also be of value to doctors and other specialists in an examination of patients with various types of aphonia or other kinds of paralysis.

PSYCHOLOGY

Gault, Robert H., Northwestern University, Evanston, Illinois. *Studies on the psychology of touch.* (For previous report see Year Book No. 27.)

Since September 1, 1928—the close of the period covered by the last report of this Laboratory—we have been active along two general lines:

1. Laboratory investigations relating to the capacity of the sense of touch to discriminate among characteristics of spoken language.
2. Application of the tactual method of communicating forms of speech in an actual schoolroom situation.

Laboratory investigations have been carried on in the Psychological Laboratory at Northwestern University. The University fitted up two large rooms to accommodate the experiments. We obtained the cooperation of four graduate students and one instructor in the department, Professor Samuel N. Stevens.

In our report a year ago, we included a statement of our findings on the effect of dual simultaneous (visual-tactual) stimulation from spoken language. The records—124 in number—indicated that deaf subjects in laboratory conditions have a considerable advantage when they at the same time see the face of a person speaking and feel his words through the teletactor system.¹ That is to say, they interpret speech more successfully in conditions of dual stimulation than they do when they see the face of a speaker but do not feel his words. Earlier laboratory experience had led us to assume that this should arise from the fact that organs of touch alone provide better discrimination of *at least some speech characteristics* than the eyes of the lipreader alone are able to furnish.

On the other hand the suggestion was made by a committee of the National Research Council that the apparent advantage may have arisen merely as a consequence of *accessory stimulation*; in other words it may be an effect of distracting stimuli. In view of the exceedingly hazy nature of the literature on such effects, this is a far-fetched suggestion. Nevertheless we decided that the time required for examining it might not be illy spent. Accordingly, a graduate student, Mrs. Libby Bass, has gone into the matter experimentally.

Her experiment fell into two parts: in the first part the object was to find in which of two situations hearing subjects, in suitable conditions, could learn lip-reading the more readily: (1) When they were enabled to see the face of the speaking experimenter but received no other controlled stimulation, (2) when they saw the face of the speaker and at the same time received continuous tactual stimulation that had no relation to the experimenter's spoken words.

In the second part, the aim was to find whether the same subjects could learn the more readily in the first or the second of the following conditions: (1) When they saw the face of the speaker but received no other controlled stimulation; (2) when they saw the face of the speaker and at the same time felt her words through the teletactor system.

¹Our report on this subject is soon to be published in the Jour. of Abnor. and Soc. Psychol.

It was desirable to employ observers who had, at the outset, no lip-reading ability. Mrs. Bass selected hearing subjects therefore.

If tactual stimuli as mere distraction served as an aid in the earlier experiments by which we established an advantage for dual stimulation over single stimulation, it would seem to be a fair hypothesis that subjects can learn to lip-read under conditions of assumed distracting tactual stimuli with greater facility than when no such alleged distraction is present. This was Mrs. Bass's assumption and she accordingly set up an experiment in learning. We are now speaking of the first part of the experiment.

STIMULI

The material to be learned consisted of sentences—two lists of twenty each. The experimenter meant to make them of equal difficulty. As a matter of fact one proved to be somewhat easier than the other. This was of no consequence, however, because each list was given both in the distraction situation and in the non-distraction situation. The two alternated throughout.

EQUIPMENT AND METHOD

A sound deadening—though not sound-proof—closet was provided in which the experimenter took her position during an experiment. This was a brick-walled-and-ceilinged-cell 4 by 5 feet, padded on the inside with woolen blankets. A double door closed the room. Each door shut against strips of felt and each one also was covered with blankets. In each door was a pane of glass 5 by 6 inches set against strips of rubber. Two lamps were suspended within, one at each side of the window, to assure uniform lighting of the experimenter's face behind the glass. The subject seated outside, and 15 feet distant, could then see the experimenter's face distinctly. The experimenter in this situation pronounced the stimuli without voice. This was the best guaranty against auditory stimulation. It had earlier been discovered that our deaf subjects were quite as able to read lips when speech was without voice as when words and sentences were vocalized. (Subject F., totally deaf, showed in November 1928 by her reactions to 100 sentences and 100 isolated words that it was of no consequence whether the stimuli were voiced or not.)

So in a non-distraction series the experimenter behind the window pronounced—more accurately, whispered—her twenty sentence stimuli and the subject or observer attempted to write the sentence. He was required to write a word if he could recognize no more and to put it upon his paper among dashes to represent as nearly as possible its relative position in the sentence.

Two or four such series were pronounced in the course of a laboratory session, the distraction and the non-distraction situations alternating. At the end of the session the experimenter and observer cooperated in marking the words that had been recognized, counted them and computed a score that indicated the percentage of recognition based upon the total number of words. The observer received no suggestions whatever to aid him in learning, except that in the course of checking up he knew where he had succeeded and where he had failed. This condition made learning difficult; it

was all the more so because the sentences were isolated; they were not associated as in continuous discourse.

The foregoing description of technique applies equally to the non-distraction and to the distraction series.

It now remains to describe the means by which tactual distraction was obtained in the alternating series. The rotating disc of a victrola was the sole mechanism. A circular sheet of blotting paper was attached to it. Bars of the same material were attached to the sheet. They were of varying width and were laid down in irregular order. A shelf was erected over the circumference of the disc. The subject sat with his left arm resting upon the shelf and with his fingers resting lightly upon the rotating disc. Thus, throughout the series, the subject received a continuous tactual stimulation due to friction between his fingers and the moving surface. The mechanism of the victrola produced no auditory disturbance and the slight noise due to friction between the disc and the fingers was entirely eliminated as far as the subject was concerned by lightly plugging his ears. After the subjects had attained a certain degree of proficiency in the conditions described above, we undertook the second part of the experiment: to find in which of the following conditions the same subjects could the more readily learn to interpret two new groups of sentences—twenty in each. The conditions were these: (1) Lip-reading without tactual accompaniment; (2) lip-reading plus the feel of the spoken sentences mediated through the teletactor.

If the teletactor contributes stimuli that have any more than mere distracting value, and in addition to what vision affords, the progress of learning in the second condition should, in favorable circumstances, be more satisfactory than in the first.

Owing to the difficulty of making our partially sound-proof closet sufficiently secure against the transmission of auditory impressions from the experimenter to the subject, we resorted to the expedient of placing the subject by the side of a tightly closed window in one building and the experimenter upon the porch of an adjacent building. For in this section of the experiment as a whole the experimenter must speak aloud—at least in those series in which the teletactor is employed. The whisper will not actuate the instrument. Speaker and subject were then separated by 75 feet of open air and by a closed window. By test we determined that no auditory cues were carried through the air directly from the speaker's mouth to the ears of the subject.

It remained then to eliminate the possibility of auditory cues from the receiver in the subjects' fingers. This we were able to accomplish in the manner we have made customary in our laboratory practice. A cylindrical box 18 inches in diameter and 30 inches in depth was brought into use. It was filled with sawdust except that from one end there projected into its middle point a sleeve of hair felt. The left hand and fore-arm of the subject fitted snugly into the sleeve and at the bottom he held the receiver of the teletactor system. This left him free to write with his right hand.

The experimenter held the transmitter of the system not before her mouth or against her cheek but closely against her larynx. This detail of pro-

cedure was adopted in order that the observer should have a full, unobstructed view of her face in the act of speaking. In one respect, it must be said, this method afforded an obstruction to the use of the teletactor: it is impossible for the subject, in such a situation, to have full advantage from distinctions of feel among the consonants, excepting gutturals and perhaps among the vowels too. Some of these differences have been described in our earlier publications.

In the situation described here, the subject can gain whatever advantage there may be in the feel of accents, emphases, variations in tempo and perhaps some changes in pitch.

It is necessary to remark finally, before passing on to describe the results of the experiment, that one of the two hearing subjects (McK) had no experience whatever with the teletactor prior to her cooperation in this phase of the experiment. She is an office secretary of more than average alertness. Her training has not prepared her to foresee what possible advantages might accrue from the procedure that has been described. The other subject (G) is the writer of this report. He had had experience with the teletactor and knew what to look for when it is in use. However, he had acquired no skill in using it that was comparable to the acquisitions of deaf subjects in the Laboratory.

RESULTS

It must be confessed that the data obtained in either part of this experiment are too limited to afford the basis for a general conclusion.

As to the first part, however, they offer no suggestion of aid from tactual stimuli. As a matter of fact, the term "distracting" does not describe the stimuli; for there is no evidence of distraction. We continue to use the term for the sake of convenience. There is only this qualification to be made: that at the outset of the experiments, the tactual impressions from the revolving disc interfered with attention to the visual stimuli. This interference, however, was of very short duration. The subjects very quickly began to neglect the tactual stimuli.

As to the second part—when the use of the teletactor was invoked in series alternating with "straight lip-reading" series—one subject (McK. who as we have already said had had no experience with the teletactor and who had not been instructed as to what advantage in detail she might possibly find in its use) showed no clear difference in progress of learning between the series with the teletactor and the series without it. However, before the experiment was finished, she was saying that she had greater confidence in her judgments when tactual stimuli accompanied the visual than when visual impressions were alone.

On the other hand, G.—who, as has already been said, was acquainted with the teletactor and had some knowledge as to the kind of cues it should afford—made a somewhat better learning record with the instrument than without it.

But the second part of the experiment, like the first, was not sufficiently extended to yield the most reliable results either positive or negative. It is appropriate to recall that our earlier deaf subjects, whose experience showed

an advantage from dual stimulation, had had a median of 87 hours of Laboratory training before the tests were made. Furthermore, with one exception among 22 subjects, they had been reading lips more or less perfectly during from eight to twenty-five years.

Our experience with this experiment provokes a further observation, the worth of which can be determined only by many times more extended research than has been done in this instance: it is probable that in order to reap the maximum advantage from dual stimulation, response to either the tactual or the visual stimuli must have approached the automatic stage. At any rate, it is probable that this is essential before striking results can be observed. Playing a piano and simultaneously reciting verse is a case that is somewhat in point. One or the other process must be fairly automatized before both can be done at once with facility.

A corollary to the foregoing is this hypothesis: if we take a group of young deaf children who are wholly untrained in the reception of speech and attempt to teach them by the methods of the instructor in lip-reading and by the tactual method at the same time, we may, for a long period, observe no tangible result (except a more than ordinary interest in speech) until a considerable body of automatic responses to spoken language shall have been developed. The hypothesis has not yet, however, been adequately tested.

IS IT ONLY BY MEANS OF DIFFERENCES IN GROSS PATTERN THAT SENTENCES ARE DISCRIMINATED THROUGH THE TELETACTOR?

By "gross pattern" applied to spoken language we mean the rhythm of speech, the distribution of accents, emphases and pauses, and variations in tempo and pitch. It requires no demonstration that these characteristics of speech are great aids to hearing people. The meaning of a sentence may depend upon the location of emphasis within it.

The question at the head of this section would be answered by showing that the feel of consonantal or of vowel qualities, for example, plays a part in tactual discrimination. Mrs. Sylvia V. R. Rose, a graduate student, accordingly has undertaken a preliminary study bearing upon this point. She constructed four lists of "sentences" to serve as stimuli. The "sentences" were series of nonsense words. In the first every syllable is "rō." The first "sentence" in that list is "ró—ro ró ro—ro ró ro—ró." The dashes indicate the location of pauses; single quotes indicate emphases. No two sentences differ except as to location of pauses and emphases. The patterns are simple.

In the second list, the vowel (long o) is kept constant throughout. It is always inserted between two consonants but there is a wide variation among the consonants that were employed. Thus: "Bo'v—roc vod' tob—kqr mot lor—gol."

In a third list both vowels and consonants are varied. Thus: "Bo'v—ric vid' teb—kor mot lir—gal."

Finally a fourth list of sixty such "sentences" combines all of those in the preceding three groups.

The results of experiments that extended over a period of three months with daily practice indicate decisively that if observance of gross pattern alone is sufficient for discrimination, no other criteria are employed. That subjects are capable of making use of consonantal and vowel criteria, however, is demonstrated by the fact that in relation to the fourth list (60 sentences combining the three other lists) C. made an identification score of 81 per cent. In other words, he surmounted the difficulty due to like gross patterns in which the only differences were in consonantal and vowel composition.

This finding is quite in accord with preliminary results obtained more than a year ago when we were enquiring into the soundness of a statement from a committee of the National Research Council to the effect that it was only gross pattern (rhythm and distribution of accents and emphases) that enabled our deaf observers to discriminate sentences tactually. In that connection, we had recourse to four sentences that were alike in gross pattern but differed in vowel and consonantal composition. Three deaf subjects were employed and the sentences were presented in short series of ten each till each one had been presented 20 times. The three subjects identified them in 72.5, 62.5 and 80 per cent of instances respectively.

We have not yet complete evidence on the question raised at the head of the section. But as far as it goes, it unquestionably indicates that the feel of much finer characteristics than gross pattern assists in the tactual discrimination and identification of spoken sentences.

THE LOCATION OF ACCENT IN BI-SYLLABLES

That the location of accent in words of more than one syllable and of emphasis within a sentence assist in carrying meaning to people who hear needs only to be mentioned to assure its recognition as a truth. They have acquired this value only in the course of becoming accustomed to speech and hearing. But it is not only as a carrier of meaning that accent and emphasis function as characteristics of spoken language. By breaking up the monotony of spoken discourse, they contribute to the pleasure that both hearer and speaker find in language as it is spoken.

Accent, however, as a term applied to stress and duration of a syllable in a polysyllabic compound played next to no part whatever in the experiments on dual stimulation already referred to. This is obvious for the reason that every one of 200 words from which we selected stimuli for our tests on recognition of isolated words was a monosyllable. Moreover more than 91 per cent of words in 116 sentences from which we selected stimuli for tests in the recognition of sentences were monosyllables also. We have, within the year now ending, completed a set of experiments on the location of accent in bi-syllabic compounds. We had, indeed, much earlier made experiments of this nature upon two hearing subjects involving 10,140 judgments apiece. The results indicated the possibility of locating accent by aid of tactual cues alone in 91 per cent of cases. No attempt was made at that time to compare with lip-reading.

TOUCH AND VISION COMPARED IN RESPECT TO THE LOCATION OF ACCENT

It seemed desirable to make such a comparison. Accordingly, we went about the task.

The experiment, as a whole, is in two sections that differ only in respect to the stimuli. In the first section, the stimulus was "loos-loos" (oo as in boot) accented now on the first syllable and now on the second. In the second section, the stimulus was "dub-dub" (short vowel) accented on the first or the second syllable. The syllable was duplicated to assure that, apart from the effect of accent, each part of the word would be transmitted with equal distinctness, whether to the eye of the subject or to his touch organs through the teletactor.

Except as indicated in a control experiment described below, the stimuli were always presented in the following manner:

Subject and experimenter were seated face to face and six feet apart. The stimuli were arranged in short series of ten. Five times in each series the experimenter accented the first syllable and five times the second. The order was irregular. Lip-reading and touch-reading series alternated. In the latter, the experimenter's face was screened from the subject's view. In each series, the transmitter of the teletactor system was held firmly against the experimenter's larynx and the receiver was in the subject's fingers. Only in the Touch series was the circuit made and it was only in this series, therefore, that the instrument was actuated. The experimenter pronounced the stimuli with as nearly normal energy and tempo as he could control. The subject responded with the word "first" or "second" according as he thought the first or second syllable received the accent and the experimenter made the record. There was a grand total of 1,070 reactions to the two stimulus words.

Excepting as described later, two experimenters—G. and C.—were employed in turn. Each of them has been associated with this Laboratory from the beginning of experiments with the teletactor.

The subjects were four deaf adults aged 24, 25, 28 and 60. Their audiometric records for the better ear in each case range from 10 to 25 per cent; a loss of from 75 to 90 per cent. Two were Grade A as lip-readers; the others were mediocre.

RESULTS

Lip-readers of Grade A located accent correctly by visual stimulation alone in around 74 per cent of instances; by tactual stimulation alone in around 85 per cent of instances. Mediocre lip-readers, on the other hand, made a record of around 65 per cent by visual stimulation and around 85 per cent by tactual stimulation.

CONTROL

It would be possible, in work of this nature, for experimenters who know the purpose of the experiment and who are interested in it to "throw" the result unconsciously. In this case, both G. and C. did their best to control their manner of speech. But complete mastery of one's voice is probably impossible. Accordingly, we imported a control experimenter, D (an

instructor in the department of Psychology in Northwestern University), who was completely in the dark as to the nature and purpose of the experiment until after his participation in it had been completed. He was advised at the outset that when all should be ready, he should pronounce a certain nonsense word "loos-loos": that his accent should be placed upon one syllable or the other to be determined in each instance by a second experimenter saying "first" or "second." D was then seated six feet from the subject and facing her. He was blindfolded. He thus was unable to see her fixing her lips to say "first" or "second" to indicate her judgment as to the location of the accent. He could not, therefore, involuntarily give her a signal indicating that she was right or wrong and so afford her an opportunity to correct herself. Furthermore, on account of his ignorance of the purpose of the procedure, he had no motive for manipulating his voice.

The second experimenter, G, took up her position behind the subject and out of her sight. She indicated her judgment as to the location of D's accent by raising one finger or two. G kept the record.

In both the lip-reading and the touch-reading series, the receiver of the teletactor was held in the subject's fingers and the transmitter was against D's larynx. The instrument was actuated only in the touch series.

The first series was for lip-reading. At its end G announced a rest period of one or two minutes. During this interval, without D's knowledge, he suspended a screen between D and F and threw the switch. The subject had in the next series to base her judgment only upon the tactual impression of D's speech. In this manner, lip-reading and touch-reading series alternated until ten of each (100 judgments) had been completed.

The results were as follows: Correct judgments—lip-reading, 49 per cent; touch-reading, 86 per cent.

The low lip-reading score in this case, compared with the same subject's score in relation to G. and C., already recorded, is accounted for on the ground that D's speaking face is relatively immobile.

AN EDUCATIONAL EXPERIMENT IN A PUBLIC SCHOOL FOR THE DEAF

In September 1928, at the invitation of the administrative officers of the Chicago School Board, we installed the teletactor system in one room of the Alexander Graham Bell School for the Deaf. The writer is very happy to express his keen sense of obligation to General Superintendent William F. Bogen, to Dr. Frank G. Bruner, Superintendent of Special Education, and to Miss Marie Mattocks, Principal of the Alexander Graham Bell School and to the Illinois Bell Telephone Company—particularly to Mr. Gruentzer for his engineering service.

By aid of the Telephone Company's engineers, each pupil's desk was equipped with both a receiver and a transmitter. The desk of the director of the group, Miss Marné Lauritsen, is equipped in like manner and, in addition, with a switchboard. All the pupils can at once feel the director's voice and, by throwing the appropriate switch, any pupil can be enabled to speak through his transmitter against all the fingers in the room, including the director's and his own. This detail of apparatus has made it possible to stir up a great deal of rivalry in the use of speech among the deaf pupils.

It is proper to say here that the Illinois Bell Telephone Company has equipped each desk also with an ear-phone so that one or two pupils who have some residual hearing may receive some auditory stimulation simultaneously with tactual and visual.

The school authorities have given us complete responsibility for the training and education of our group of deaf children, not only in the reception and expression of spoken language, but in reading, number, etc. We have been able, therefore, to make up and use reading material that we, ourselves, have produced. It is based upon the words that are most commonly used in the first grades in schools for hearing children and for deaf children also. Incidentally, it may be said that there is very little uniformity in this respect among schools for the deaf.

In respect to silent reading, we are making quite as great a departure from conventional methods as the teletactor represents in relation to speech and the interpretation of speech; for we are pushing the children ahead as fast as possible in the acquisition of a silent reading vocabulary and in its use without regard to the limitations of their lip-reading and speaking vocabularies. This we regard as entirely justified theoretically and our experience emphatically confirms the theory.

We have free access to control groups in the Alexander Graham Bell School. On the ground of convenience, we have made use of two such groups. One of these is a year in advance of our experimental group and the other is a year behind it. The controls have been made use of only in relation to progress in the use of speech and in silent reading.

The report below indicates in detail what tests have been made upon the experimental group and upon the controls, and the results of their application.

Report of Experimental and Control Groups at Alexander Graham Bell School

I. Pupils of Experimental Group	Age at end of school year
Estella Chalfant	10 years
Adelle Chalke	9
Lois Gillack	9
Gottlieb Hoppe	9
Chester Kazmierski	9
Sigmund Rosinski	10

II. TESTS ADMINISTERED—

A. Intelligence (performance tests, October 18, 1928):

1. Cube Imitation Test
2. Seguin Form Board
3. Manikin Test
4. Feature Profile Test
5. Two Figure Form Board
6. Mare and Foal Test and Healy Pictorial Completion

The first six were scored according to Arthur's Point Scale. The resulting mental ages and I. Q.'s are as follows:

Name	M. A.		I. Q.
Chester	9 yrs.	5 mos.	109
Sigmund	7	8	.83
Adelle	6	0	.85
Gottlieb	6	11	.83
Lois	7	10	.84
Estella	8	7	.85

B. Educational Tests:**1. Speech Test:**

On October 9, fourteen listeners, students in the University and unfamiliar with deaf people, were asked to listen to the experimental and control¹ groups read isolated words and sentences. Each child was given a different set of twenty words and ten sentences. He read one at a time while the listeners recorded what they heard. On May 28, 1929, the test was repeated. The results are as follows:

Control Group					Experimental Group			
Isolated Words			Sentences		Isolated Words		Sentences	
Av. per subj....	Oct. 9	May 28	Oct. 8	May 28	Oct. 9	May 28	Oct. 9	May 28
P. Ct. gain.....	0.65	1.45	4.45	8.25	.35	1.115	6.25	6.85
	.....	123.0	.....	85.3 ²	.....	228.5 p.ct.	.....	9.6 p.ct. ²
Av. p. ct. gain					119.0			

2. Lip-reading Test:

On October 8, 1928, a lip-reading test was administered as follows. A list of 130 words was prepared. These were words which the children were supposed to have been taught prior to October 1928. Objects representing these 130 words were placed upon a long table. In case no object was available, a picture was drawn upon the blackboard. A response was scored as correct if the child picked out or pointed to the correct object or picture. This test was repeated on June 13, 1929. The same experimenter, whom the children had not seen except for a brief period of two weeks in March, performed the experiment.

Name	October	June	Improvement
Sigmund.....	33 p. ct.	69.2 p. ct.	109.7 p. ct.
Estella.....	25.3	67.6	167.1
Chester.....	24.6	70.0	184.5
Lois.....	53.8	79.2	47.2
Adelle.....	33.8	73.8	118.3
Av. Group Scores.....	34.1	71.9	110.8

3. Reading Tests:

On October 18, 1928, the Detroit Word Recognition Test and Gates' Reading Tests I and II were given. The children could not handle Gates' type III nor Haggerty's, so these were omitted. These tests were repeated June 14, 1929. At this time, the Detroit and three forms of Gates' test were also given to the Control Group and to the class just below the Experimental Group. The results are as follows (see tables, p. 413):

¹ The control group is the class just above the experimental group.

² The disparity between 85.3 per cent and 9.6 per cent is undoubtedly due in very large measure to the fact that members of the Experimental Group have been trained toward normally rapid speech with inflection; not so with the Control. Were their speech somewhat slower, their improvement over the Control in relation to isolated words would unquestionably have reacted much in their favor when they were pronouncing the sentences.

Experimental Group

	Detroit W.R.		Gates I		Gates II		Group III		Age in June
	Oct.	June	Oct.	June	Oct.	June	Oct.	June	
Estella.....	12	35	10	31	10	26	.....	11	10 yrs. 9 mos.
Adelle.....	13	29	16	36	8	18	.....	9	9 10
Lois.....	14	32	15	35	13	19	.....	9	9 0
Chester.....	4	33	0	31	0	22	.....	10	9 3
Sigmund.....	16	28	8	39	4	28	.....	13	10 0
Gottlieb.....	.....	32	.....	32	.....	.....	.....	.....	9 0
Class Av.....	11.8	33	9.8	34	7	22.6	.....	10.4	9.6 yrs.
Read. Grade.....	.....	2A	.....	2.65	.....	2.45	.....	1.75	.....
Control Group—1 yr. in advance of Exper. Group									
Class Av.....	33		34.83		20.83		11.33		11.11 yrs.
Read. Grade.....	2A		2.65		2.35		1.80		.....
Group 1 yr. behind experimental group									
Class Av.....	14.75		17.25		11.5		3		9.06
Read. Grade.....	1B		1.95		1.85		1.40		.....

4. Arithmetic Test:

On December 13, the G. C. Myer Diagnostic Test of 100 Combinations was given to the experimental group. Their scores and their subsequent scores in June are as follows:

	December	June
Gottlieb.....	50	98
Adelle.....	26	96
Sigmund.....	9	99
Chester.....	40	98
Stella.....	41	100
Lois.....	7	99
Av.....	28.8	98.3

III. SUMMARY OF YEAR'S WORK—

1. Vocabulary: (a) 281 nouns, (b) 73 verbs, (c) 27 adjectives, (d) 22 prepositions have been illustrated and put into their dictionaries. These words have been used for lip-reading, speech and language work. The verbs have been presented in the present, present progressive and past tenses.

2. Reading:

- A. Oral: (a) The class has finished Wag and Puff, (b) The Laboratory Primer has been read twice, (c) Smedley-Olsen Primer read through page 92, (d) Beginner's Book read from page 64 to end, as required in Chicago Course of Study.

- B. Silent Reading: (a) 75 sentences describing pictures in the room, (b) various performance sheets (75 different sheets), (c) work and play.
3. Arithmetic: (a) Addition—combinations to 18, (b) Subtraction—combinations to 10, (c) Number stories involving subtraction and addition.
4. Handwork: Cutting, pasting and coloring in connection with their performance sheets, i. e., all seat work was correlated with direct vocabularies or reading work. Individual calendars were made for each month. Child marked each day when he came to school; dated all papers written. Thus calendar work was made an incidental and yet vital topic.

Visiting teachers of the deaf from Milwaukee, Minneapolis and Los Angeles have commented on the unusual spontaneity in speech that our Experimental Group exhibits and in the rivalry among them.

On the basis of the showing that we have made during the year 1928-29, the school authorities have asked us to continue the work during the year 1929-30. They have undertaken to aid in the financial support of the enterprise, and the Principal of the school has offered to place another group in our hands.

It is cause for gratification that we have definite requests to supply teachers who have been trained in this Laboratory and in our classroom. Other cause for satisfaction is in the fact that Dr. David Katz of the University of Rostock, Germany, has told the writer that he has confirmed the results of this Laboratory, showing the advantage of simultaneous tactual and visual stimulation from spoken language, and that he has arranged to conduct in a schoolroom for the deaf in Berlin precisely the educational experiment that we are carrying on in Chicago—so far, at any rate, as the employment of tactual stimuli is concerned.

Bell Telephone Laboratories have equipped us recently with an easily portable teletactor which we shall begin to use experimentally in October 1929. In this apparatus, the energy is supplied by three Everready dry cells instead of a six-volt wet battery which the old outfit requires. It substitutes a mechanical amplifier in the microphone housing for the electrical device (Western Electric 7A) that we have used in the past. The receiver is a single unit instrument. The vibrating part is a metallic reed instead of a diaphragm. The reed carries a small post, about one-sixteenth of an inch in diameter, which operates against the subject's skin or nail.

During the year, as heretofore, the Laboratory has had the indispensable assistance of Dr. George W. Crane and Miss Marné Lauritsen. Miss Lauritsen has spent her whole time in the schoolroom. Dr. Crane has divided his time between the Laboratory in Northwestern University and the preparation of classroom material for Miss Lauritsen's use. Their ingenuity and acquaintanceship with the outstanding developments in educational research have made them indispensable in respect to the adaptation of hearing school methods and materials to our needs.

We are under obligation, also, to Northwestern University for having fitted up ample rooms, in addition to office space, for our use.

Pearson, Karl, and Henry A. Ruger, Teachers College, Columbia University, New York, New York. *Studies on the theory of surfaces.* (For previous reports see Year Book No. 27.)

The following report is submitted as the result of continued studies undertaken with appropriation of funds by Carnegie Corporation of New York to the Carnegie Institution of Washington for support of Generalized Frequency Surface Research:

The setting up of approximately 1000 correlation distributions on data from Sir Francis Galton's Study, previously reduced for age difference, with careful checking has occupied most of the year. The computation of the frequency constants for these correlation surfaces is now in progress. There are 28 correlation distributions on the entire population of over 7000 males. For each of these 28 tables there are 28 restricted age-group tables. The nature of the correlations in the general population and their relation to the correlations in the special age groups is the immediate objective. The empirical result of greatest novelty is perhaps that concerning the correlation with other traits of swiftness of blow. The eight traits studied are stature, weight, span, sitting-height, stronger grip, vital capacity, pull and swiftness of blow.

SEISMOLOGY

REPORT OF THE ADVISORY COMMITTEE

(For previous reports see Year Books Nos. 20-27.)

As in other recent years the activities of the Advisory Committee in Seismology have taken two principal directions. One, the establishment of fixed points of reference or landmarks throughout the earthquake region of California, whereby major displacements of the earth's crust can be determined both in magnitude and direction with high precision. It is hoped by this means to discover slow creeping movements, if such exist, which may conceivably forecast an impending earthquake. It is also planned that suitable bench-marks shall be available after any earthquake to measure by their displacement the character and extent of the movement. This plan has been vigorously supported and in large measure carried out by the Geodetic Division of the U. S. Coast and Geodetic Survey under the able direction of Dr. William Bowie. As a result of this cooperation we have today a network of primary triangulation over so much of the west coast region as is known to be frequently visited by earthquakes. This triangulation net is "anchored" both at the northern and southern extremities and in the middle by branch arcs extending eastward to connect with the general network defining our national system of boundaries in regions less subject to seismic disturbance.

Similarly a number of lines of precise levels span the general region occupied by the Seismological Laboratory and outlying stations in such manner as to cross the fault zones known to be active in southern California. These will be extended at a later date when opportunity offers.

Having thus made provision in a general way for the appropriate measurement of larger crustal movements the next step seemed to be to provide for detailed observations of certain active spots on the known fault zones, in such number and of such high precision as to permit the analysis of the structural movements taking place there. For this purpose a region just south of Los Angeles and extending northeastward across all the fault zones between the sea and the mountains was selected and so thickly sprinkled with monuments that it should be quite practicable to differentiate between the surface movement at the fault trace and the movement at varying distances back from it.

The second major interest of your Committee has been the instrumental study of the minor earth movements as they occur from day to day and are recorded upon appropriate instruments of our own development at the Seismological Laboratory and its associated stations.

These two chapters of our activity will be treated separately below.

GEODETIC WORK IN CONNECTION WITH SEISMOLOGICAL STUDIES¹

Congress has continued to make an appropriation of \$10,000 to the Coast and Geodetic Survey for use in executing geodetic surveys in regions of seismic activity. During the past year the field work done under this appro-

¹ Dr. William Bowie.

priation consisted of an arc of close triangulation extending from Newport Beach northeastward toward Lucerne Valley. The distance between the terminal points of this arc is 90 miles, of which about 60 miles (from Newport Beach) was completed last year. The Director of the Coast and Geodetic Survey has announced that this work will be completed during July and August 1929 and in addition that it will be extended from Lucerne Valley northward to connect with the triangulation of the 35th parallel arc. A base line will also be measured to control the lengths of triangle sides in Lucerne Valley.

The triangulation running northeastward from Newport Beach consists of a wide scheme of first-order triangulation with the stations on commanding points of peaks and ridges and a subsidiary scheme of many stations located relatively near together in the three major fault zones which are crossed by the arc of triangulation. The spacing of the subsidiary stations was determined by Mr. George L. Bean, chief of the triangulation party, in collaboration with Mr. H. O. Wood, seismologist, and Professor John P. Buwalda of this Committee.

On the completion of the work in southern California, mentioned above, Mr. Bean will move his party and equipment to the vicinity of Point Reyes, northwest of San Francisco, and extend an arc of triangulation from there eastward across the San Andreas and Haywards faults, following the same general plan that was used in the Newport Beach—Lucerne Valley arc. Mr. Bean will confer with Professor Buwalda in regard to the location of the stations near the fault zones which will be crossed by this Point Reyes line.

In December 1928 special publication No. 151 of the U. S. Coast and Geodetic Survey appeared. It is entitled *A Comparison of Old and New Triangulation in California*, by Dr. William Bowie, Chief of the Division of Geodesy of the U. S. Coast and Geodetic Survey. The manuscript of this publication was used in the preparation of the report of the Advisory Committee in Seismology for 1928. This report on the old and new triangulation in California is now obtainable from the Superintendent of Documents, Government Printing Office, Washington, D. C. (15 cents), and is vitally necessary to any competent study of regional horizontal displacement in the California earthquake zone.

In the office of the U. S. Coast and Geodetic Survey a similar adjustment of the first-order leveling in California has been in progress, including both that which was carried out as a part of the program for seismic studies and leveling which had been executed by engineers of the Survey for other purposes. In this adjustment the tidal planes at San Diego, San Pedro and San Francisco were held as having zero elevations. There were 14 loops of leveling amounting in all to about 2,500 miles. The elevations resulting from this adjustment are still in manuscript form but are available for consultation at the U. S. Coast and Geodetic Survey in Washington, D. C.

As the fiscal year 1929 is closing, the Division of Geodesy is engaged upon an adjustment of the combined level nets of the United States and of Canada involving 67,000 miles of leveling. In this adjustment only the tidal station at Galveston, Texas, is being used and the plane of mean sea-

level at that place is given zero elevation. The result of this adjustment will supplement the results obtained from an adjustment of the United States net alone which was made in 1927. According to that adjustment there is a slope of mean sea-level upward with increased latitude, both on the Atlantic and on the Pacific coasts. There is a slope downward along the Gulf coast from Galveston to St. Augustine, Florida. The tidal planes on the Pacific coast were found to be approximately two feet higher than the average mean sea-level at the tidal stations on the Gulf and on the Atlantic coasts. This upward slope of mean sea-level to the northward seems to be rather general, for it occurs in the British Islands, in France and also in Russia. It is probable that it also occurs in other countries, but no reports from them are now available.

After this adjustment has been completed, a second adjustment is to be undertaken with mean sea-level held at zero at the various tidal stations on the Atlantic and Pacific coasts of Canada and of the United States and of the Gulf coast of the latter. When the results from this second adjustment are available, then it will be possible to select what may be called standard elevations for the leveling bench-marks throughout the interior of the United States, along its coasts and in Canada. These are the elevations which will form the basis for leveling in regions subject to earthquake where it is desired to learn the amount and distribution of local vertical movement of the earth's surface. Any part of the leveling network of the United States, amounting to more than 50,000 miles, can then be used in the study of earth movements in the future. The adjustments mentioned above will furnish the differences in elevation between contiguous bench-marks, which would be compared with the differences in elevation obtained by new leveling immediately after an earthquake or in a region where distortion of the earth's surface is suspected.

What has been said above in regard to first-order leveling may also be said of the first-order triangulation net of the country to which allusion was made in the report of last year. This adjustment covers about 13,000 miles of arc of triangulation extending from the 98th meridian westward to the Pacific coast.¹

The results of this adjustment proved to be most satisfactory, as is indicated by the very small errors in the closures of the 16 loops into which the net was divided. The average closing error of a loop was about $1/450,000$ of the distance around it (averaging about 1,200 miles). The poorest closure was $1/165,000$. These closing errors clearly show the high accuracy attained in first-order triangulation. They also give an idea of the accuracy with which a long distance may be measured across country. The methods employed in first-order leveling are such as to make most of the errors in observations accidental in their effects.

The officials of the Coast and Geodetic Survey have now begun the adjustment of the eastern half of the triangulation net of the United States. This triangulation adjustment also is of great importance to the seismologist for the arcs involved, approximately 28,000 miles in total amount, will be avail-

¹ Report on the readjustment of the first order triangulation net of the western part of the United States, O. S. Adams, Serial 350, U. S. Coast and Geodetic Survey.

able for studying earth movements in New England, South Carolina and other eastern regions where there has been seismic activity. These arcs are similar in character to the first order arcs of triangulation executed in California 30 years or more ago, which recently furnished the basis for the determination of the earth movements there by comparison with the new results obtained in the triangulation undertaken recently and reported from time to time in the Annual Reports of this Committee. The Coast and Geodetic Survey is supplying invaluable data for the determination of the directions and extent of earth movements in regions which now are or which may become seismically active in the future.

WORK OF THE SEISMOLOGICAL LABORATORY¹

The fundamental work of this program—the instrumental registration, together with auxiliary recording, field investigation, etc., of the earthquakes of the local province, as well as distant shocks, at the Seismological Laboratory and at the secondary stations at Riverside, Santa Barbara, La Jolla and Mount Wilson, the analysis and measurement of the seismograms, comparisons with the data of reports and field inquiries, and consideration of the geological and physical conditions and problems indicated and suggested by the characteristics of the seismograms, and of the auxiliary data—this fundamental work of routine and research has gone on satisfactorily and with much increased effectiveness. The progress in this has been very encouraging, all the more since certain necessary and desirable equipment is not yet everywhere available—notably adequate time recording and vertical-component seismometers.

The office handling of the records, both instrumental and otherwise, has been further systematized and facilitated and improvements in the "seismometric bookkeeping" procedure have been introduced. The body of records is already substantial and is growing steadily. The record card files already possess much of value and interest.

More time than in previous years has been available for, and has been devoted to, the studious and thoughtful consideration of both the general aspects and of many of the details of the more strictly seismologic problems of local and regional character. This work is fundamental and eventually it will lead to published results. Here in Southern California we are still confronted with numerous problems none of which are solved completely, and few of them can be solved, or approximated satisfactorily, until a considerable body of data has been accumulated. Also, data of still greater accuracy than any yet available, except in isolated cases, appear to be required for the solution of many of these problems. In other cases data from a larger number of stations, or from stations distributed more evenly or more widely, or both, appear to be desirable, and even essential.

NEW STATIONS

During the year station shelters have been built in the Owens Valley at the Haiwee and the Tinemaha reservoirs, to provide for secondary stations at these places. The finishing of the interiors of these is in progress as the year comes to an end. It is expected that they will be available for the installation of equipment in the very near future. These have been erected

¹ Extracted from the Report of H. O. Wood, Research Associate in Seismology.

through the courtesy of the chief officials of the Bureau of Water Works and Supply of the City of Los Angeles—the aqueduct organization, to whom an expression of our grateful appreciation is due for their friendly and substantial cooperation in this research program.

ACCURATE TIME

Radio time signals from the stations NSS at Annapolis, NPG at Mare Island, and at times NPL at San Diego are marked automatically on the seismograms registered at the Seismological Laboratory, usually at 9 a.m. and 12 m., occasionally at 7 p.m., and frequently at 10 p.m., Pacific Standard Time. Infrequently there have been failures in this time checking, due usually to defective sending, rarely to defective receiving, and on occasion to other causes. The correction to the time-marking clock has been known accurately during most of the time. Also, for several months past the records written at Mount Wilson have had radio time signals marked automatically upon the seismograms. Thus it has been possible to compare with high accuracy the arrival times of shock phases on the records written at these two stations. Unfortunately these two stations are too close together for the useful application of this accuracy to pressing problems of wave speed and source location in many instances.

In the report for the preceding year reference was made to a plan for recording at each seismologic station code signals sent out by some powerful commercial radio station, and by comparison of these code signals with the minute marks made by the time-marking clock at each station to reduce the time-keeping at all stations to a common basis. This was proposed as an adequate, though inconvenient, substitute for common time-keeping by radio time signals sent each minute from a central point to be received and marked at each station. (This better plan is thus far impracticable on account of cost.)

The substitute plan required some development and testing which has been carried through successfully, and for some weeks near the close of the year such recording of code signals in comparison with the station clocks has been in routine operation at the Seismological Laboratory and at Riverside. It will soon be put into operation at the other stations.

This method of time control has already yielded important data and demonstrated conclusively its usefulness, notwithstanding its inconvenience and the opportunity it offers for errors of reading. By means of it, under the best circumstances arrival times can be determined with an error not exceeding one-tenth of a second. In ordinary circumstances the error is less than a whole second, and usually it does not exceed a small fraction of a second. For our purposes the operation must be improved until the error in ordinary circumstances does not often exceed one-tenth of a second. We anticipate no difficulty in accomplishing this as the development proceeds.

RECORDED SHOCKS

Utilizing such improved arrival-time data the speeds of the waves identified as \bar{P} and \bar{S} are found to be very close to 5.4 km./sec. and 3.2 km./sec. respectively, which are close to the values determined elsewhere. Higher

speeds, of course, are found for the P_n and S_n waves, and other P and S waves as now identified.

Study of the shocks for which we have the best data shows that the determination of epicentral distances by means of the formula $\Delta=9.25(S-P)$ is satisfactory when the distances so determined range from about 100 to 300 kilometers, but not so outside these limits. At distances of less than 100 kilometers the depth of the focus must be taken into account, but even after care is taken of this it is found that a different multiplying factor is required—a value lying between 7 and 8, instead of 9.25 above. At distances of less than 100 kilometers $\Delta=K(\bar{S}-\bar{P})$, where the calculated value of K is 7.8+. Results similar to these have recently been found to apply in Japan and elsewhere. In past years many different values for K have been suggested, based upon differing foundations of experience. The value of K is affected, of course, by the complexity of the path of the ray, and the different materials traversed. It affords only an approximate value of the epicentral distance.

In many cases the exact identification of phases is difficult, especially where the origin-distance is 300 kilometers or more, owing both to the ordinary complexity of the registration and to the successive appearance of two, or three, P and S phases or more. As data accumulate, the improvement of tables or curves of arrival times for the local region should serve gradually to resolve these uncertainties, particularly after sufficiently accurate time keeping and time comparisons become available at all our stations.

A large number of local earthquakes have been registered at the stations of our network during the year. It is not feasible to enumerate or tabulate these until later on account of various uncertainties not yet cleared up. A great majority of these shocks were too small to be felt. Many of them have been registered at one station only, or under other circumstances which have prevented reasonably sure location of their epicenters. However, a large number of shock origins have been located, either very accurately or fairly so. In addition a considerable number have been located less well, but approximately nevertheless.

The mapping of these determined shock origins discloses in the immediate region some thirty-five epicentral tracts which may be termed *habitual*. It is not considered that the loci of origin have been *strictly identical* in these cases, perhaps not in any two cases; but these loci of origin have *clustered* in very small areas from many of which several or even many shocks appear to have emanated. This has occurred to an unexpected degree.

There is not sufficient space here for even a briefly descriptive list of all these habitual epicentral tracts. Several of them are the sites of relatively recent strong and moderately strong local shocks such as the Santa Barbara earthquake, the Calxico earthquake, etc. Others have been brought to light somewhat unexpectedly by the instrumental work, notably two located in the desert region east of the San Bernardino mountains, well to the northeast of the San Andreas fault, where it was considered probable that the ground was quiet and stable. The suggestion is strong that these are associated with a fault recognized by Dr. Robert T. Hill and by him named the "Pinto" fault. A shock at 6^h 42^m a.m. on September 5, 1928, strong

enough to be felt over a wide area in Southern California and which was followed during the ensuing 24 hours by 69 after shocks strong enough to be registered, appears to have emanated from one of these sources.

During the year no shocks have occurred in the local province strong enough and so located as to cause structural damage or similar effects.

A marked tendency has been noted for epicenters to cluster thickly along the San Jacinto fault between the neighborhood of Coahuila Valley and the Superstition Mountains.

Along the San Andreas fault several epicenters have been determined between the vicinity of Yucaipa and that of Whitewater; one has been located also near San Bernardino and one, probably, in the Cajon Pass. A few shocks have been recorded from a source not far from Coalinga, probably on the San Andreas fault. Except for these, this major fault has remained unexpectedly inactive this year, like last. Mention should be made, however, of an epicentral tract located near Niland in Imperial County, from which several shocks have emanated. This is near the hypothetical southeastward extension of the San Andreas fault, well beyond the point to which it has been traced with certainty.

Two epicenters have been located in the southern part of the San Joaquin Valley—utilizing field evidence to supplement the instrumental findings—which suggest activity on an extension of a fault which passes through the McKittrick oil field and is there very strongly suspected of activity.

There is an habitual epicenter located south of the Mexican border near the head of the Gulf of California. This has been located only approximately. The principal shock from this source occurred on October 5, 1927, and was considerably stronger than the shocks which originated not far from Calexico. Very considerable activity has persisted and several of the later shocks have been felt at Calexico, El Centro, Yuma, and even San Diego.

Probably still more active is the source of the shock of November 4, 1927, off the west coast of Santa Barbara County. Disturbances emanating from this have been recorded frequently at Santa Barbara and a considerable number have been strong enough to write easily recognizable records at Pasadena and even at Riverside. Some have been reported in the press as felt in the Lompoc district.

In passing, continued activity of slight character on the Inglewood fault has been indicated, and two epicenters indicate activity on the Garlock fault which vaguely marks a northern boundary for the Mojave Desert.

There is not space here to refer in detail to other interesting epicenters or to discuss their distribution. Only those of chief interest are mentioned above.

However, it should be mentioned that many of the shocks from near Santa Barbara are registered only at the Santa Barbara station, while others of these registered at Santa Barbara with considerable amplitude are often barely registered at our other stations. It is interesting, also, that near Santa Barbara there are *two* distinct, well-marked shock sources. All of the stronger shocks have emanated from one of these.

IMPROVEMENTS IN INSTRUMENTS

The method for rotating drums by Warren motors operated by current supplied from 50-watt, electron tubes, where the frequency is controlled by a 60-cycle tuning fork which is itself maintained in oscillation by the electron-tube circuit, has been worked out satisfactorily. This method is free from electrical contacts and was outlined as a project in the report for the preceding year. It has proved successful, but the control circuit has had to be made complicated and the cost of installation is undesirably high. Fortunately, however, experience gained in connection with it has led, with little further development, to a system which, though it has been under test for only a short time, appears sure to prove satisfactory.

This newer development is simpler and less expensive than any previous systems. It consists of a vibrating element, a reed, fork or possibly a piezoelectric plate, maintained in oscillation by an electron-tube circuit, with an amplifying circuit. Precisely controlled 60-cycle current thus provided will operate two Warren motors. One of these will keep time as precisely as the vibrating element. The other is in face-to-face juxtaposition with a Warren motor supplied with current from a small motor-generator driven by direct current supplied by the station storage battery which is kept floating on the power mains. Whenever the Warren motor driven by the motor-generator current gets ahead, or behind, by a small fraction of a second, an adequate electrical contact is made, which, by a change of resistance, slows down or speeds up the motor generator by causing a change in the field current of the direct-current motor. By means of this device the frequency of the current supplied by the motor generator is kept, within exceedingly narrow limits, equal to the frequency of the controlling, vibrating element. Sufficient current is provided by the motor generator to operate a considerable number of Warren motors which will run, within exceedingly narrow limits, as well as the Warren motor clock controlled directly by the vibrating element. In this way very uniform rotation of the recording drums is secured and in addition very good time keeping. If it proves practicable to use a temperature-controlled piezoelectric quartz plate, or vibrator, as the fundamental frequency control it should provide unexcelled time keeping, and at the same time secure uniform drum rotation with practically the same accuracy as that of the clock. The use of the quartz vibrator has not yet been investigated. Operation with the reed and tuning fork has been demonstrated, and has been under practical test for some time with excellent results and equally good promise.

One of the most important, practically, of the problems attacked is that of providing suitable small mirrors for use on the suspended system of the torsion seismometers. On account of the small dimensions of the inertia mass the mirror has to be small in area and thin so as not to contribute too greatly to the inertia system, thus reducing the lever magnification. The mirror must also be plane and brilliant. To provide such mirrors is an old and vexed problem. After exhaustive experimentation, during which trial was made of beryllium, platinum on glass, silver on the front surface of the glass protected in various ways (by a thin coat of platinum, by lacquer applied variously, etc.), stellite, etc., etc., it was concluded that the best

solution would be the old one, *viz*, plane-parallel glass mirrors silvered on the back with a protective coating. Quartz and also quartz-glass were tried and laid aside. An immense amount of effort has been devoted to developing a successful technique for this which will enable us to produce adequate mirrors. It is as yet uncertain whether an unqualified success will be achieved, but the outlook is hopeful.

A re-design of the optical system for use with the seismometers was carried through successfully using a double cylindric lens system, analogous to one described by Hardy in the Journal of the Optical Society of America. It is estimated that the available light for registration is increased about six times. It is expected that this system will be used for recording.

RECOMMENDATIONS

It is recommended that provision be continued:

- (1) For further experimental work on vertical-component instruments for the stations already designated.
- (2) For the further study of minute-to-minute time signals for simultaneous record at all of the stations.
- (3) For further experimental work in the study of cumulative stresses (tilt mechanism).
- (4) For two additional branch stations at appropriate points to be selected.

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INDEX

	PAGE		PAGE
Abbot, Charles G., Publication by.....	70	Anthropometry and Psychometry, Stand-	
Measurement of Spectral Energy of		ards in.....	63
Stars.....	105, 112, 134	<i>Anton Dohrn</i>	277
Solar Observations.....	105	Apia Observatory.....	118, 210, 227, 240
Absorption Spectra of Phenyl Osazones....	171	Appalachians, Eugenical Studies on.....	65
Acoustical Society of America.....	402	Appleton, E. V.....	214
Adams, Edward F., Displacements of Lines		Archæology, Middle American.....	9
of Sun.....	105, 119	Report of Investigations.....	299
Publications by.....	89, 121	Arizona, University of.....	242
Adams, Frederick.....	337	Arnold, Ralph.....	424
Adams, L. H.....	vi	Ascidians, Influence of Light on Larvæ of...	284
Adams, Mildred, Publication by.....	88	Asia, Field Operations in.....	233
Adams, Walter S.....	vi, 1, 401	Astronomical Union, International.....	106
Address on Board <i>Carnegie</i>	55	Athletic Success, Heredity Factor in.....	60
Chairman Advisory Committee.....	102	Atmosphere, Composition of Sun's.....	122
Publications by.....	70, 71, 87, 111, 131	Atmospheric-Electricity.....	214, 216
Report on Mount Wilson Observatory..	101	Atmospheric Oxidation of Carotin.....	173
Stellar Spectroscopy... 104, 111, 112, 131,	133	Auditors, Report of.....	99
Adelaide, University of.....	149	Ault, J. P.....	vii
Adult Anatomical Studies.....	27	Address on Board <i>Carnegie</i>	50
Aeroarctic, American Section of.....	245	Balloon Work on <i>Carnegie</i>	226
Agassiz, Alexander.....	v, x	Command, <i>Carnegie</i>	209
Aitken, John, Collected Papers of.....	269	Commission for Planning Oceanographic	
Akeley, Carl.....	16	Work in Arctic.....	245
Alaska Agricultural College and School of		Magnetic Work on <i>Carnegie</i>	225
Mimos.....	210, 220	Oceanographic Work.....	225
Albany General Catalogue.....	93	Publications by.....	70, 77, 219, 248, 249, 256
Albrect, Sebastian.....	vi	Report Cruise VII.....	221
Alexander Graham Bell School for Deaf...	410	Aurousseau, M., Publications by.....	71, 78
Alexander, J., Publication by.....	74	Austin, L. W., Night-Reception Measure-	
Algæ, Marine.....	297	ments.....	213
Allen, E. T.....	vi, 338	Australia, Magnetic Survey.....	210, 233
Publications by.....	70, 78	Australasian Antarctic Expedition.....	338
Allen, Ezra, Publications by.....	70, 88	Autecology.....	193
Allen, S. J. M.....	212	Avery, Amos G.....	vi
Allergy in Tuberculosis.....	12	Mutation in <i>Datura</i>	35
Alpine Laboratory.....	193	Avery, Priscilla.....	358
American Academy of Teachers of Singing..	402	Publications by.....	71, 75
American Association of Anatomists.....	9	Ayers, Alden F.....	144
American Historical Association.....	85	Aykroyd, W. R.....	380
American Historical Review.....	85	Babcock, E. B.....	viii
American Medical Association.....	61, 402	Publications by.....	71, 79
American Museum of Natural History.....	330	Studies in Genetics.....	359
American Otological Society.....	62	Babcock, Harold D.....	vi, 3, 4
American Philosophical Society.....	41	Bands of Atmospheric Oxygen.....	107, 120
Amœbæ, Marine and Fresh-water.....	286	Collaboration with Geophysical Lab-	
Amory, Copley.....	337	oratory.....	70
Amphibia, Meninges in.....	22	Infra-Red Solar Spectrum,	
Anastasi, Anne, Comparative Mental Tests.	64	104, 105, 107, 119, 129	
Anatomical Studies, Adult and Comparative.	27	Investigations of Nebulæ.....	103
Anderson, John A.....	vi	Neon Lamps for Comparison Spectra..	113, 140
Electrically Exploded Wires.....	139	Publications by.....	71, 89, 121
Examining Figure of Mirror or Lens....	114	Badger, Richard M., Publications by.....	71, 398
Optical Testing with Foucault Knife-		Bailey, I. W., Publication by.....	72
Edge.....	141	Structure and Function of Cambium of	
Publication by.....	70	Higher Plants.....	334
Seismology Committee.....	424	Baldwin, George J.....	v
Spectra of Metals.....	104	Baly, E. C. C.....	172
Vacuum Discharges.....	113, 138	Banker, Howard J., Heredity in Human	
Antarctic Regions, Studies in.....	234	Families.....	35, 62
Ant-Eater, Parasites in Ovaries of.....	25	Publications by.....	72
Antevs, Ernst.....	viii		
Publications by.....	70		
Report on Glaciation Studies.....	387		

	PAGE		PAGE
Banta, A. M.	VI, 85	Boss, Lewis	VI
Physiological Studies on Thermal Clones	43	Bowen, I. S., Publications by	73, 87, 396, 397, 398
Publications by	72, 74, 84	Bowen, N. L.	VI
Researches in <i>Cladocera</i>	35, 41, 42	Publications by	74, 77, 81, 82
Basal Metabolism, Instrumental and Physi- ological Technique for	54	Bowie, William, Committee on Seismology	219, 416
Bass, Libby	403, 404	Publication by	417
Bassett, John S., Publication by	68	Boylan, R. K.	269, 270, 271
Batchelder, R. M., Determination of Carbon- Dioxide Content	153	Brayton, Ada M.	105
Bauer, Louis A.	VII, 40, 244, 245	Brain of Ornithorhynchus	18
Director Department of Terrestrial Magnetism	209	Brantley, L. R.	348
Publications by	72, 250	Breder, C. M. jr.	VII
Baxter, W. P., Publications by	72	Flying Fishes and their Allies	277
Bean, George L.	417	Breit, Gregory	VII
Beckman, A. O.	349	Atomic Physics	210, 214
Béhounek, F., Electric Data, Nobile's Arctic Expedition	220	Lectures by	245, 246
Beirut, Observatory of American College at	118	Magnetic Forces between Electrons and New Kinds of Interactions	215
Bell Telephone Laboratories	213	Publications by	74, 250, 251
Belling, John	VII	Quantum Mechanics	215, 246
Chromomeres and Genes	35	Brickwedde, F. G., Publication by	91
Cytological Investigations of	35, 206	Bridges, C. B.	141
Publications by	72	Germinal Material in Relation to Hered- ity	338
Benedict, Cornelia Golay	150	Publications by	69, 74, 76, 77
Publications by	72, 157	Brigham, Carl C.	35
Benedict, Francis G.	VII, 7, 370, 371	British Museum, Excavations by	330
Publications by	72, 78, 87, 89, 154, 155, 156, 157, 158, 159	Brookings, Robert S.	V, XIX
Report on Nutrition Laboratory	147	Brooks, C. F., on Meteorological Program	221
Research on Basal Metabolism	35, 54	Publications by	74, 252
Bennett, B. L., Yucatan Medical Expedition,	299, 301, 302	Brown, Howell C., Night-Reception Meas- urements	213
Bennett, R. D., Publications by	81, 397	Brown, L. A., Publication by	74
Benson C. C., Racial Metabolism	154	Brown, V. R., Assistant Watheroo Magnetic Observatory	287
Bequaert, J. C., Yucatan Medical Expedition	299, 301, 302	Brown University	245, 359
Berg, Tor	86	Bruggencate, P. ten, Observations on Ce- pheid Variables and Stars in Clusters	106
Bergeron, T., Publication by	73	Bruner, Frank G.	410
Bergner, Dorothy	VI	B-Type Stars with Emission Lines	132
Mutation in <i>Datura</i>	35, 40	Buffalo Museum of Science	230
Bibliography of Publications	70	Builder, G.	VII, 237
Bigelow, H. B.	337	Publication by	252
Billings, John S.	V, X	Burkenroad, Martin	VII
Bingham, Harold C., Publication by	73	Pelagic Organisms	277, 282, 283
Biological Sciences, Research in	7	Burnett, Edmund C.	VII
Biology, Report on Investigations in	334	Publications by	74, 87
Birge, R. T.	103, 138	Burwell, Cora G., B-Type Stars	111, 132
Birmingham, University of	150	Stellar Spectra	105
Bishop Museum in Honolulu	336	Button, R. H.	161
Bjerknes, V.	VIII	Buwalda, John P.	VIII, 401, 417, 424
Investigations in Meteorology	362	Investigations in Paleontology	388
Publications by	73	Publications by	69
Blakeslee, A. F.	VI	By-Laws of Institution	XIII
Publications by	73	Byrd Antarctic Expedition	218, 220, 230, 234, 244
Researches on <i>Datura</i>	34, 40, 41, 44	Cactus Tissue, Water Intake of	189
Blanchard, Lillian F., Retired	99	Cadwalader, John L.	V, X
Blinks, L. R.	VII	Cairns, J. E. I., Observer Watheroo Magnetic Observatory	237
Studies on <i>Valonia ventricosa</i>	277	Publication by	252
Blish, Helen H., Indian Art	360	Calcareous Soils, Growth on Highly	184
Bogen, William F.	410	Caldwell, M. L., Publication by	88
Boron in Sun, Identification of	123	California Institute of Technology	101
Boss, Benjamin	VI	Calorimetry	152, 193
Report Department Meridian Astrom- etry	93	Cambium of Higher Plants	334
		Cambridge, University of	150
		Cameron, G. Harvey, Publications by	33, 396, 397

	PAGE		PAGE
Campbell, J.....	169	Clausen, J.....	357
Campbell, W. W.....	xix, 424	Clements, E. S., Cycles in Climate and Vegetation.....	197
Address on Carnegie.....	44	Clements, Frederic E.....	vii
Cape Town, University of.....	220, 230	Investigations in Ecology.....	193
Caracol, Report on Excavation of.....	303	Climatic Cycles and Tree-Growth.....	199
Carbon Dioxide, Tests of Absorbents for.....	150, 151	Publications by.....	69, 91
Carbon, New Isotope of.....	138	Coalstad, S. E.....	237
Carnegie, Andrew.....	ix, 148	Coast and Geodetic Survey.....	210, 219, 242, 416
Carnegie.....	17, 148, 149, 209, 216, 337	Coastal Prairie and Desert Plains.....	201
Carnegie Corporation of New York,		Coba Expedition, Report on.....	328
56, 142, 377, 395, 402, 415		Cobel, Arthur B., Publications by.....	75
Carnegie Foundation for Advancement of Teaching.....	60	Cohn, E. J.....	373, 377
Carnegie Museum of Pittsburgh.....	230	Cold Spring Harbor, Anniversary at.....	18, 25, 58
Carnegie Ridge.....	223	Cole, Whiteford R.....	v
Carotin, Structure of.....	172, 173, 174	Colhoff, John.....	360
Carpenter, T. M.....	vii	Collins, J. L.....	358
Carbon Dioxide after Ingestion of Sugars	150	Publications by.....	75
Gas-Analysis Apparatus.....	150	Collins, Warren E., Gravity-Survey on U. S. Submarine.....	157, 219
Lectures on Basal Metabolism.....	149	Colorado River, Delta of.....	185
Metabolism with Sugars and Muscular Work.....	150	Commonwealth Solar Observatory.....	118, 244
Publications by.....	75, 154, 155	Compton, A. H.....	246
Cartwright, C. Hawley, Publications by.....	71, 398	Compton, K. T.....	viii
Carty, John J.....	v, xix	Spectroscopy.....	395
Address on Celebration of 25th Anni- versary.....	32, 66	Conger, Paul S.....	vii
Publications by.....	75	Diatoms of Tortugas.....	277
Casa Redonda, Report on.....	310	Conklin, E. G., Address.....	25, 66
Case School of Applied Science.....	239	Connecticut Agricultural Experiment Station	369
Casson, Benedict, Publications by.....	75, 396, 397	Connor, Elisabeth.....	105
Castle, W. E.....	viii	Constant, F. W., Publications by.....	75, 398
Heredity in Small Mammals.....	334	Cooke, C. Montague jr.....	336
Publications by.....	75	Coolidge, Cascade-Method of.....	214
Castillo, Felipe.....	302	Corbitt, Elsa B., Observations on Mice of Leukemic Strain.....	56
Castration Studies.....	24	Cornell University.....	213
Caswell, S. W.....	237	Cornier, G. W.....	7, 8
Catalytic Hydrogenation of Carotin.....	174	Publication by.....	68
Catterall, Helen T., Publications by.....	68, 89	Coropatchinsky, V.....	vii
Cells, Growth of Endocardial.....	15	Calorimetry with Geese.....	152
Cells, Photoelectric.....	140	Publications by.....	73, 158
Cellular Waves.....	362	Corpuscle, Constriction of.....	207
Cercariae from Tortugas.....	292, 295	Cortical Localization of Movements of Facial Vibrissae.....	20
Chaney, R. W.....	vii, 388	Cosmical Sciences, Informal Committee on..	244
Researches in Paleobotany.....	203	Cossmann, H., Catalogue of Malignant Tissue. Publication by.....	13 81
Chapman, S., Lunar Atmospheric Tide at Apia.....	241	Coward, Katherine H.....	267, 382
Charger, Samuel.....	360	Crampton, Henry E.....	viii
Charlot, Jean.....	299	Variations of Partula.....	336
Cheltenham Magnetic Observatory.....	242	Crampton, Henry E. jr.....	336
Chemistry, Report on Investigations.....	348	Crane, George W.....	414
Cheyenne River Reservation.....	360	Crowell, W. R., Publication by.....	75
Chichen Itzá, Investigations at.....	10, 299, 312	Crystalline Substances, Structure of.....	348
Chick, H.....	380, 382	Cummins, H., Publication by.....	68
Chicago, University of.....	359	Study of Volar Pads.....	8
Chondrification of Hand and Foot.....	8	Cycles in Climate and Vegetation.....	197
Christ-Church Observatory.....	242	Cytological Investigations.....	206
Christie, William H., Measurement of Stellar Spectrograms.....	105, 111, 129, 133	Cysts of Different Ages, Infectivity of.....	290
Christman, Guinevere, Studies on Pigeons.....	35, 152	Dahl, O.....	vii
Chromomeres, Studies on.....	35, 207	Land Magnetic Survey.....	230, 233
Chromosomes, Studies on.....	40, 207, 355, 356	Publication by.....	74
Cladocera, Mutations in Parthenogenetic... Sex Control in.....	41 51	Work in Atomic Physics.....	214
Clark, C. B.....	24	Dalton, R. H., Publications by.....	75
Clark, H. L.....	viii	Darton, N. H.....	387
		Date Seeds, d-Mannose from.....	174

	PAGE		PAGE
Datura, Gene Mutations in.....	40, 41	Eastcott, E. V.....	358
Davenport, Charles B.....	vi, 34	Eaton, V. J.....	vii, 239
Publications by.....	69, 76	Echinometra at Tortugas.....	297, 347
Report on Department of Genetics.....	33	Eekart, C.....	248
Davenport, Frances G., Publication by.....	68	Eclipse, Lunar Radiation during an.....	128
Davies, F. T.....	216, 218, 220, 234, 240	Ecology.....	193
Day, Arthur L.....	vi, 14	Eddy, Walter H.....	viii
Publications by.....	70, 75, 78	Physiological Functions of Vitamins....	377
Report as Director of Geophysical Lab- oratory.....	67	Edinburgh, University of.....	150
Report on Seismology Committee.....	401	Edmonds, H. M. W.....	vii, 224, 243
DeGaris, C. F., Publications by.....	76	Eggleton, P.....	367
Relation of Muscle Groups.....	29	Electricity, Experimental Work in Terres- trial.....	216
Delano, Frederic A.....	v, xix	Ellerman, Ferdinand.....	vi
deLaubenfels, M. W., Publications by.....	76	Magnetic Field in Sun-Spot Groups....	107
deMars, P. A.....	213	Publications by.....	76
Demerec, M.....	vi	Solar Observations.....	104
Publication by.....	76	Spectroheliograms.....	116
Studies on Mutable Genes.....	37, 39, 45, 344	Ely, J. O.....	382
Denton, James.....	380	Emerson McMillan Observatory.....	118
DeSachy, G. P.....	270, 271	Embryo, Volar Pads in Human.....	8
Desert Laboratory, Activities at.....	164, 182	Embryo with Ten Somite-Pairs.....	7
Desert Perennials, Transpiration Rates of..	186	Embryonic Hearts, Pulsation Rate of Iso- lated.....	14
Desert Plants.....	188	Embryology, Report of Department of.....	3
Desert Sanatorium in Tucson.....	242	Emission Lines, B-Type Stars with.....	132
Diatomaceae, Investigations on.....	336	Endocardial Cells, Growth of.....	15
Dickinson, R. G.....	349	Endocrine Studies in Pigeons.....	54
Publications by.....	72, 76	England, J.....	400
Dickson, L. E., Mathematical Studies.....	361	Ennis, C. C.....	vii
Publication by.....	361	Earth's Magnetic and Electric Activi- ties.....	211
Dillon, R. T.....	349	Physical Oceanographic Work.....	219
Publication by.....	76	Publication by.....	252
Dobshansky, Th., Publication by.....	76	Revision of Data and Compilations from Carnegie.....	219
Dodge, Cleveland H.....	v, x	Environmental Influence, Cooperative Studies on.....	180
Dodge, William E.....	v	Enzymes, Amylases and Related.....	351
Dole, Malcolm, Publication by.....	86	Epstein, Paul S.....	109, 124, 399, 401
Dominion Astrophysical Observatory.....	132	Publications by.....	76, 396, 398
Donath, W. F.....	377, 378	Erlanson, Eileen.....	181
Donnan, Elisabeth, Publication by.....	91	Estabrook A. H.....	vi, 35
Douglass, A. E.....	viii	Heredity in Human Families.....	35
Climatic Cycles and Tree-Growth.....	199	Population of Southern Appalachians..	65
Dowd, Merritt.....	145	Publications by.....	76
Drosophila, Mutable Genes in.....	37, 45	Eugenical Studies on Population of Southern Appalachians.....	65
Drummond, J. C.....	379, 382	Eugenics Record Office, Library of.....	65
DuBridge, Lee A., Publications by.....	76, 396, 397	Eugenics Research Association.....	64
Duke University.....	213	European Stocks, Incidence of.....	65
DuMond, Jesse W. M., Publications by.....	76, 396, 397, 398	Evans Memorial Hospital.....	149
Duncan, John C., Photographic and Spec- troscopic Studies.....	106, 109, 111, 124, 125, 129, 131, 133	Evjen, H. M., Publications by.....	76, 398
Publications by.....	76	Ewing, F. J.....	348
Dunham, Theodore jr.....	vi	Publication by.....	76
Publication by.....	76	Executive Committee, Report of.....	93
Stellar Spectroscopic Observations.....	105, 106, 111, 131, 133, 134	Explosions, Wire.....	139
Dunn, Leslee C., Color Genes in Mice.....	58	Eye Defects in Mice.....	58
Dutcher, R. A.....	382	Fascia, Macrophages of Deep.....	11
Duvall, C. R.....	vii	Facial Musculature.....	29
Earth's Magnetic and Electric Activities.....	211, 212, 243	Facial Vibrissae.....	20
Publications by.....	76, 252	Farr, A. Gertrude, Nitrogen of Food Samples.....	153
Dwight, C. H., Studies of Atmospheric Pot- ential-Gradient.....	212	Publication by.....	154
Earth-Currents.....	217	Fenner, Charles P.....	v
Earth-Resistivity.....	218		

	PAGE		PAGE
Fenner, C. N.....	vi	Gas Analysis.....	150
Publications by.....	77, 79, 80	Gases in Trunks of Trees.....	166
Ferguson, Homer L.....	v, xix	Garven, H. S. D., Racial Metabolism.....	149, 154
Fetus, Pathology of.....	9	Gault, Robert H., Psychology of Touch....	403
Fetuses, Technique of Measuring.....	32	Publication by.....	77
Field Museum of Natural History.....	330	Gaviola, E., Atomic Physics.....	214
Financial Statement.....	61	Interpretation of Quantum Theory....	216
Finn, Mary D., Publications by.....	73, 156, 157, 158	Publications by.....	77, 257, 258, 259
Fishes of Tortugas.....	288	Gazin, Charles L.....	390
Flak, H. W.....	vii, 245	Publication by.....	391
Land Magnetic Survey.....	211, 230	Gebhardt, Robert E., Atmospheric-Elec-	
Publications by.....	77, 252, 253, 254	tricity.....	216, 239
Results Obtained at Sea.....	209	Genes, Chromomeres and.....	35, 37
Fleming Deep.....	229	Gene Mutations in.....	38, 39, 40
Fleming, John A.....	vii	Genes in Mice.....	58
Assistant Director Department of Ter-		Genital Tract, Development of.....	9
restrial Magnetism.....	209	Genetics, Report of Department of.....	33
Commission for Atmospheric-electric		Report of Investigations in.....	355
Work in Arctic.....	245	Geodetic Work in connection with Seismo-	
Cooperation in Cosmical Sciences....	244	logical Studies.....	416
Earth's Magnetic and Electric Activities		Geophysical Laboratory.....	338, 451
Editor.....	245	Publications of.....	77
Executive Committee American Geo-		Report of Director of.....	67
physical Union.....	245	Geophysical Union, American...245, 259, 263, 265	
Member International Committee on		Germ Plasm.....	35, 44
Oceanography.....	245	Germinal Material in Relation to Heredity.	338
Publications by.....	77, 248, 250, 256	Germination of Covillea Seeds.....	187
Revision of Data and Compilations		Gibbs, J. Willard, High Dispersion of	
received from <i>Carnegie</i>	219	Stronger Lines of Ionised Praseody-	
Secretary American Geophysical Union.	245	mium.....	113, 138
Flemion, Florence, Publication by.....	87	Thermodynamic Relations in Multi-	
Flexner, L. B., Meninges in Amphibian		Component Systems.....	67
Embryos.....	22	Gibson, R. E.....	vi
Publication by.....	68	Publications by.....	78, 86, 82
Flexner, Simon.....	v	Gifford Pinchot Expedition in South Pacific.	338
Flying Fishes.....	277, 279	Gilbert, Cass.....	v, xix
Foot, Muscles of.....	30	Gillett, Frederick H.....	v, xix
Forbes, W. Cameron.....	v, xix	Gilman, Daniel C.....	v, x
Forbush, S. E.....	vii, 239	Gish, O. H.....	vii
Publications by.....	77, 257	Atmospheric-Electricity.....	216, 217, 245
Forest Service.....	145	Consulting Physicist.....	218, 264
Fox, E. L.....	vii	Earth-Currents.....	218
Absorbents for Carbon Dioxide.....	150, 151	Member Committee on Radium Poison-	
Gas-Analysis Apparatus.....	150, 151	ing.....	218
Metabolism with Sugars and Muscular		Meteorology American Geophysical	
Work.....	150	Union.....	245
On Respiratory Quotient.....	152	Newly Designed Apparatus and Im-	
Portable Respiration Apparatus.....	151	provements.....	217, 240
Publications by.....	76, 154, 155	Potential Multiplier designed by.....	217
Francon, Marcel.....	351	Publications by.....	78, 245, 259, 260, 261, 275
Publication by.....	86	Terrestrial Electricity.....	216
Franklin, Mrs. George S.....	48	Gland, Seasonal Changes in Pituitary.....	55
Fraps, R. M., Oxygen Consumption of		Glucose, Utilisation of, by Leaves.....	175
Sections of Planaria.....	190, 191	Glyceraldehyde, Interconversion of.....	168
Publication by.....	77	Goettsch, M.....	385
Frayne, John G., Publications by.....	77, 396, 398	Goets, Alexander, Publications by.....	78, 396, 397
Frew, William N.....	v, x	Goetze, Richard E.....	336
Friedgood, H. B., on Tumor-cell.....	12	Goiter, Heredity of.....	61
Publication by.....	77	Goldsmith, G. W.....	vii
Furlong, Eustace L.....	390, 391	Anthokinetics.....	194
Publications by.....	89, 391	Goodner, K., Yucatan Medical Expedition,	
Funk, Casimir.....	379	.....	299, 301, 302
Gabritachevsky, E., Publication by.....	74, 77	Goranson, Roy W.....	vi
Gage, Lyman J.....	v, x	Publications by.....	78, 77, 82
Gall-Bladder, Permeability of Epithelium of	31	Thermodynamic relations in Multi-	
Gardiner, M. S.....	347	Component Systems.....	67

	PAGE		PAGE
Grafe, E.....	149	Heidel, W. A.....	VIII
Graham, H. W.....	VII, 230	History of Early Greek Thought.....	394
Grant, Sherwood B.....	VI	Publications by.....	79, 394
Grassland Climax.....	200	Heinemann, R. L. S.....	392
Grave, Caswell.....	VII	Heisenberg, W.....	215, 246
Pelagic Organisms.....	277, 283	Publication by.....	246
Gregory, P. W.....	7, 3, 5, 334, 336	Heredity in Small Mammals.....	334
Publications by.....	78, 88	Of Athletes.....	60
Green, Charles, Heredity of Sex-linked		Of Goiter.....	61
Characters.....	61	Of Mental Traits.....	62
Green, John W.....	VII, 212, 243	Of Otosclerosis.....	62
Greig, J. W.....	VI	Of Sex-linked Characters.....	61
Grindley, E. N., Resurvey of South Africa..	231	Herrick, Myron T.....	V, XIX
Grodzinski, E., Lymphatic Hearts in Fossil		Death of.....	I
Reptiles.....	32	Hees, Frank.....	337
Publication by.....	78	Heuser, C. H.....	VI, 5
Guatemala, Government of.....	330	Publication by.....	68
Gucker, Frank T., Publication by.....	86	Heusi, Wm. M., Experimental Taxonomy..	175
Guda, B. C.....	379, 382	Hewett, E. L.....	301
Gudger, E. W., Publication by.....	282	Hewitt, Abram S.....	V
Guffin, Flora.....	99	Hexoses, Interconversion of.....	167
Gurin, S.....	380	Hibben, J. H.....	VI
Gustafson, Florence L., Publications by....	78, 156	Hickox, Joseph.....	105, 107, 116
Habitat Studies at Desert Laboratory.....	183	Hicks, C. S., Racial Metabolism.....	149, 153
Hackett, Charles W., Publications by.....	86	Higginson, Henry L.....	V, X
Hamulide, Sound-Production in.....	277, 282	Hill, E. C., Publication by.....	79
Hafenrichter, A. L., Anthokinetics.....	194	Radiographic Study of Vascular System	31
Hafnium, Spectrum of.....	137	Hill, Robert T.....	421
Hafstad, L. R.....	VII	Hill, S. N.....	132
Atomic Physics.....	214	Hilton, H. M., Methods for Determining	
Publications by.....	78, 262, 263	Carbon-Dioxide Content.....	153
Hale, George E.....	VI, 101, 118	Hincke, W. B.....	348
Observations of Solar Phenomena....	104, 107	Publication by.....	85
Publications by.....	78	Hines, M., Ornithorhynchus Brain.....	18
Hales, Wayne B., Publications by.....	78, 397	Publications by.....	79, 80
Hall, E. L., Publication by.....	91	Skeletal Muscle Tonus.....	20
Hall, H. M.....	VII	History of Science, Report on.....	359
Experimental Taxonomy.....	175	Historical Research, Report of Department	85
Hall, Lawrence P., Investigations on Atomic		Historical Sciences.....	86
Weights.....	351	Hitchcock, Ethan A.....	V, X
Publications by.....	86	Hobbs, J. R., Disease in Rabbits.....	14
Hand, E. R.....	240	Publication by.....	79
Haney, C. W.....	358	Hodges, Clarence, Publications by.....	79, 397
Hanna, G. Dallas.....	338	Hoge, Wendell P.....	129
Hanson, Herbert C., Publication by.....	69	Infra-Red Solar Spectrum Lines.....	105
Harnwell, Gaylord P., Publications by....	79, 396	Lectures by.....	115
Harradon, H. D.....	219	Publication by.....	71
Publications by.....	79, 247, 259, 263	Höjer, A.....	385
Harriman, Mrs. E. H.....	18	Holbrook, Bess L.....	299, 300, 301
Hartman, Carl G.....	VI	Hollingshead, Lillian.....	357, 358
Placentation Studies on Macaque.....	23, 25	Publications by.....	71, 75, 79
Publications by.....	79, 80	Honeywell, H. E.....	382
Harvard Astronomical Laboratory.....	213	Hookway, L. C.....	390
Harvard Medical School.....	149	Hopfield's Ultra-Violet Spectra of Carbon	
Harvard Observatory.....	117	Monoxide.....	138
Harvard Yucatan Medical Expedition....	299, 301	Hopkins, Dwight L.....	VII
Harvey, E. M., Organography of Cylindro-		Locomotion in Marine Amcebe.....	277, 286
puntias.....	165	Horse, Thoroughbred.....	59
Hawaii, University of.....	149	Horst, Kathryn, Albino Rat.....	153
Hay, John.....	V, X	Houston, William V., Publications by....	80, 398, 398
Hay, Oliver P.....	VIII	Hoover, Herbert.....	V
Publication by.....	68	Howe, P. R.....	385
Hearts, Pulsation Rate of Isolated Embry-		Howe, William W.....	V, X
onic.....	14	Howell, A. Brasier.....	27
		Publication by.....	80

	PAGE		PAGE
Huancayo, Instituto Andino of.....	239	Kassel, L. S.....	349
Huancayo Magnetic Observatory, 149, 210, 218, 237		Publications by.....	80
Hubble, Edwin.....vi, 1, 102, 103, 106		Kaster, Katherine.....	105
Extra-Galactic Nebulae. 104, 110, 125, 126, 127		Katz, David.....	414
Member Advisory Committee.....	102	Keck, David D., Experimental Taxonomy..	175
Publications by.....	80, 109, 125	Keenan, George L.....	377
Huber, E., Facial Vibrissae of Opossum.....	20, 30	Kellogg, Remington.....	viii
Publications by.....	80	Publication by.....	81
Huff, C.....	vii	Researches in Palaeontology.....	389
Atmospheric-Electric Apparatus. 217, 240, 243		Kendall, John C.....	148
Publications by.....	88, 264, 275	Kennelly, A. E.....	viii, 212
Hull Botanical Laboratories.....	187	Kennelly-Heaviside Layer.....	210, 213
Human Behavior, Studies in.....	13	Kenny, Richard.....	164
Humason, Milton.....	vi, 1	Kenrick, G. W.....	213
B-Type Stars with Emission Lines.....	132	Key, K. M.....	382, 385
Nebular Spectroscopy.....	112, 113, 126, 133	Kerr, A. J.....	299, 300, 301
Publications by.....	70, 80, 91	Kerr, R. W.....	383
Velocities of Faint Nebulae..	104, 109, 111, 126	Kidder, A. V.....	vii, 11
Hunt, C. H.....	382	Early American History.....	35
Hunter, R. H., Development of Utero-		Kilborn, L. G., Racial Metabolism.....	149, 154
Vaginal Canal.....	9	Killip, E. P.....	239
Publication by.....	80	Kilmartin, J. O.....	299, 300, 301, 302, 312
Huntington, J. L.....	10	Survey.....	300
Publication by.....	80	King, Arthur S.....	vi, 3
Hutchinson, Charles L.....	v, x	Investigations of Nebulae.....	103
Ilium of Adult Primates.....	29	Publications by.....	81
Indian Art, Report on.....	360	Spectra of Rare-Earths. 104, 112, 136, 137, 138	
Inglis, E. R.....	390	Kinnersley, H. W.....	379
Ingram, S. B., Publications by.....	396, 397, 398	Kinney, H. S.....	143
Inguanex, Dom Mauro.....	386	Kinney, W. L.....	144
Irwin, M. R.....	335	Kline, H. W.....	213
Isis, Publication of.....	359	Kirschman, H. D., Publication by.....	75
Italia, Nobile's Arctic Expedition.....	220	Kodakkanal, Sun Photographs from.....	116
Interferometers, Stellar.....	130	Kolar, J. J.....	212
Jacomini, Clement, Spectroheliscopes.....	142	Publications by.....	81, 263
Jack, R. W.....	32	Korff, S. A., Publication by.....	395
Publication by.....	80	Kracek, F. C.....	vi
James, Mrs. W. B.....	48	Publications by.....	81, 79, 81, 82
Jameson, J. Franklin.....	85, 86	Křišenecký, Jar, Growth in Pigeons.....	35, 48
Jansen, B. C. P.....	377, 378	Ksanda, C. J.....	vi
Jeans, Sir James.....	viii, 105	Publications by.....	87, 79
Jenkins, Heroy.....	vi	Land Magnetic Survey.....	230
Jennings, Walter.....	48	Lanes, Theophil.....	65
Jobling, J. W.....	56	Langley, Samuel P.....	v, x
Johnston, H. F.....	vii	Langworthy, O. R., Histological Studies of	
Publications by.....	80, 263	.....	15, 17, 18
Watheroo Magnetic Observatory.....	237	Publication by.....	68, 81, 15
Jonas, Leon, Racial Metabolism.....	154	Laughlin, H. H.....	vi
Jones, George D.....	145	Genetic Constitution of American Pop-	
Jones, L. A.....	402	ulation.....	35, 65
Magnetic Work on Board <i>Carnegie</i> ..	225, 226	Heredity of Thoroughbred Horse.....	35, 59
Jones, Sidney.....	145	Inventive Ability.....	35
Jordan, David Starr.....	390	Migration Movements.....	65
Joseph Henry Fund.....	69	Publications by.....	81
Joy, Alfred H.....	vi	Lauritsen, C. C., Publications by... ..	81, 83, 396, 397
Publications by.....	80, 88, 111, 131	Lauritsen, Marne.....	410, 414
Stellar Spectroscopy.....	104, 111, 112, 131, 132	Lawson, A. C.....	424
Joyner, Mary C., Observations for Photo-		Leavenworth, Charles S., Publication by... ..	91
visual Magnitudes.....	129	Ledig, P. G.....	vii, 238
Photographic Measurements of Stars..	105	Huancayo Magnetic Observatory.....	225, 239
Preparation of Mount Wilson Cata-		Publications by.....	81
logue.....	105, 110	Studies on Racial Metabolism.....	149
Ju Chi Li, Publication by.....	69	Lee, R. C.....	150
Kakioka Magnetic Observatory.....	229	Lee, Henry.....	32
Karol, J. J., Publication by.....	80	Publication by.....	80

	PAGE		PAGE
Lehmer, D. N.....	viii	MacLeod, Grace, Publications by.....	73, 158
Publication by.....	69	MacMillan Expeditions.....	243
Leland, W. G.....	vi, 86	Macrophages of Deep Fascia.....	11
Publication by.....	86	MacVesgh, Wayne.....	v, x
Report of Department of Historical		Magnetic Charts for Polar Regions.....	212
Research.....	85	Magnetism and Atomic Physics.....	214
Leonard, Frederick C., Publications by.....	81	Mair, Beveridge J., Publication by.....	86
Spectra of Stars.....	106, 111, 131, 133	Male Production in Rotifer.....	52
Lesage, Pierre.....	180	Mall, Franklin P.....	vi
Lewis, E. M.....	148	Mallery, T. D., Growth on Highly Calcareous	
Leukemia in Mice.....	56	Soils.....	184
Leverett, Frank.....	387	Manila Observatory.....	218, 244
Lewis, Margaret R.....	vi	Mann, Albert.....	viii
Allergy in Tuberculosis.....	12	Report on Diatomaceae.....	336
Behavior of Chicken-Tumor Virus....	13	Manometric Method, Notes on Refine-	
Catalase of Malignant Tissue.....	13	ment of.....	192
Malignancy of Cells.....	12	Marsden, E.....	240
Publications by.....	81, 86	Marsh, Hannah M., Stellar Parallaxes and	
Stagnant Blood-Cultures.....	11	Proper Motions.....	105
Lewis, Warren H.....	vi, 3, 5	Marsh, Jean M.....	46
Monocytes and Macrophages.....	11	Mason, Eleanor D., Racial Metabolism... 149,	153
Publications by.....	69, 82	Mason, Herbert L.....	204
Rhythmic Contractions of Chick Heart.	14	Mason, Karl E.....	368, 371
Leyer, C. E., Depth-Finder Repairs.....	227	Publication by.....	82
Oceanographic Work.....	225, 227	Mathematics, Report on.....	361
Lindbergh, C. A.....	12	Mattocks, Marie.....	410
Light, Velocity of.....	142	Mauchly, Sebastian J., Deceased.....	209
Lindsay, William.....	v, x	Publications by.....	82, 272
Lingnan University of Canton.....	336	Maxson, John H., Publication by.....	891
Linke, F.....	242	Mayan Research.....	331
Littlehale, A. D.....	153	McComb, H. E., Magneto-Chronograph....	240
Littlehales, G. W.....	256, 264	Publications by.....	82, 264
Lockwood, J., Malignancy of Cells.....	12	McCoy, Oliver R.....	vii
Publication by.....	81	Trematode Life Histories.....	277, 290
Lodge, Henry Cabot.....	v	McKee, Marguerite M.....	85
London, University, Imperial College of		McKibben, P. S., Monro-Kellie Hypothesis.	21
Science.....	241	McLaughlin, Andrew C.....	vi
Long, Frances.....	vii	McIntyre, G. A.....	237
Calorimetry.....	172, 193	McRae, D. B.....	350
Long, John H., Mental Tests by.....	64	Mead, Pauline.....	165
Longley, Wm. H.....	vii	Meadley, G. R. W.....	237
Executive Officer Tortugas Laboratory.	277	Medical Survey of Yucatan.....	300
Habits of Fishes and of Noddy and		Mees, C. E. K.....	119
Sooty Terns.....	277, 288	Meinss, F. A. Vening.....	5
Low, Seth.....	v, x	Gravity-Determining Apparatus	
Lowe, E. A.....	viii	.....	69, 171, 209, 219
Publications by.....	82, 386	Mellon, Andrew W.....	v
Report on Palaeography.....	386	Mendel, Lafayette B.....	viii, 1, 370
Lucas, G. H. W.....	383	Metabolism of Albino Rat.....	148
Ludy, A. K.....	242	Multiple-Chamber Respiration Appa-	
Lunar Observations.....	124, 125, 400, 401	ratus.....	153
Luminosity and Parallax, Determinations of	134	Publications by.....	82, 91
Luminosity Distribution of M-Type Stars..	136	Vegetable Proteins.....	367
Macacus rhesus.....	23	Mensel, R. H., Publications by.....	73, 397
MacCormack, Elisabeth, Stellar Motions..	105	Menstruation and Intermenstrual Bleeding.	23
MacDougal, D. T.....	vii	Mental Traits, Heredity of.....	62
Gases in Trunks of Trees.....	166	Mercury Arc, Radiation from.....	140
Growth in Trees.....	165	Meridian Astrometry, Department of.....	211
Publications by.....	69, 166	Report of Department of.....	93
MacDowell, Mrs. E. C.....	46	Merriam, John C.....	v, xix, 102, 204, 256
Publication by.....	82	Address on Celebration of 25th Anni-	
MacDowell, E. C.....	vi, 7	versary.....	18, 66
Growth of Mice.....	46, 52, 53, 56, 58	Palaeontological Researches.....	388
Publications by.....	82	Publications by.....	82
Mack, J. E., Publication by.....	395	Report as President.....	1
MacKay, Kathryn.....	299, 300, 315	Merriam Ridge.....	224
MacLaughlin, J.....	270		

	PAGE		PAGE
Merrill, Paul W.....	vi	Morris, E. H.....	vii, 11
Publications by.....	82	Preparation of Archaeological Reports..	299
Stellar Spectroscopic Investigations		Morris, Mrs. E. H., Preparation of Archae-	
104, 111, 131, 132, 133		logical Reports.....	299
Merritt, E.....	213	Morphogeny, Experimental Adaptation and.	196
Merwin, H. E.....	vi	Morrow, William W.....	v, x, xix
Publications by.....	71, 78	Death of.....	1
Metabolism Studies.....	54, 150, 152, 153	Moses, Mildred, Publication by.....	83
Meteorology, Report on.....	362	Motor Cortex, Electrical Excitability of....	19
Meteorological Investigations in Arizona and		Mount Holyoke College.....	154, 359
Northwestern Sonora.....	184	Mount Wilson Observatory.....	220
Meteorological Service of British East Africa.	220	Report of.....	101
Meta, C. W.....	vi	Moukden Medical College.....	149
Publication by.....	83	Muscle Tonus, Skeletal.....	20
Studies on <i>Sciara</i>	35, 48	Muscles of Foot.....	30
Mexico, Excavations by.....	330	Munro, Dana C.....	85
Mice, Studies on.....	46, 53, 56, 58	Muskat, Morris, Publications by.....	76, 396, 398
Michaelis, L., Behavior of Chicken-Tumor		Mutable Genes.....	37, 39
Virus.....	13	Mutations.....	37, 40, 41, 42, 45
Publication by.....	81	Myelinisation and Correlation with Reflex	
Michels, W. C., Publications by.....	79, 397	Activity.....	15, 17
Michelson, A. A.....	viii	Nabours, Robert K.....	viii
Publications by.....	83	National Academy of Sciences.....	69
Redetermination of Velocity of Light,		National Park Service.....	204
102, 105, 114, 142, 143, 145		National Research Council.....	48, 245, 403, 408
Michelson-Morley Experiment, Repetition of	143	Naumann, Erik.....	86
Michigan College of Mining and Technology	218	Naval Observatory.....	117
Michigan, University of.....	163	Naval Research Laboratory.....	213
Migration Movements.....	65	Navashin, M., Publications by.....	83
Micro-Chemical Technique.....	170	Nebulae, Researches on.....	125, 126, 127
Microphotometers.....	142	Nebraska, University of.....	360
Microscopical Society.....	337	Neon Lamps.....	140
Miller, Carey D., Racial Metabolism.....	149, 154	Nervous System.....	15, 16
Miller, H. M. jr.....	vii	Newburgh, L. H., Racial Metabolism.....	154
Behavior of Trematode Larvae.....	277, 292, 295	New Hampshire, University of.....	153
Miller, L.....	383	Newton, Harvey E.....	viii
Millikan, R. A.....	viii, 424	New Mexico, Museum of.....	301
Publications by.....	395, 396, 397, 398	New Zealand Department of External	
Report on Physics.....	395	Affairs.....	240
Milles, Bess, Heredity of Otosclerosis.....	62	New Zealand Meteorological Service.....	242
Mills, Darius O.....	v, x	Nicholson, Seth B.....	vi
Mills, E. S.....	vii	Measurements of Lunar Radiation.....	109, 124
Mills, John W.....	277	Publications by.....	84, 86
Milner, Harold W.....	vii,	Solar Physics.....	104, 107, 118, 123, 246
Micro-Chemical Technique.....	170, 172	Spectroheliograms.....	116
Mines, Bureau of.....	210, 218	Nishibe, M., Cultures of Kidney Tissue....	15
Mitchell, S. Weir.....	v, x	Growth of Endocardial Cells.....	15
Monosmith, Helen, Studies on <i>Sciara</i>	35, 48	Publication by.....	84
Monro-Kellie Hypothesis.....	3, 21, 22	Nitsulescu, Julius, Gas-Analysis Apparatus..	149
Montague, Andrew J.....	v	Noble's Arctic Expedition.....	220
Montgomery, Carol G., Publication by.....	398	Nolan, J. J.....	268, 270, 271
Moodie, R. L.....	391	Nordberg, M. E.....	349
Moon, Committee on Study of Surface		Publication by.....	86
Features of.....	106, 124, 398	Noyes, Arthur A.....	viii
Moore, Charlotte E., Publications by.....	83, 87, 89	Investigations in Chemistry.....	348
Morey, G. W.....	vi	Publications by.....	84, 350
Publication by.....	82	Nutrition Laboratory, Report of.....	147
Morgan, B. C. G.....	382	Nutrition, Report on Investigations on.....	367
Morgan, L. V., Publication by.....	69	Obreshkove, V., Oxygen Consumption of	
Morgan, T. H.....	viii	Clones of <i>Simcephalus exepinosus</i> ...	44
Germinal Material in Relation to		Publication by.....	84
Heredity.....	338	O'Brien, Martin J., Mutation in <i>Datura</i>	35
Publications by.....	69	O'Brolchain, Cilian.....	268
Morley, Sylvanus G.....	vii	Ocean Work.....	221
Report on American Archaeology		Oceanography, International Committee on	
299, 300, 301, 327, 329			221, 245

	PAGE		PAGE
Odin, M., Racial Metabolism.....	149, 154	Pease, Francis G.....	vi, 1, 108, 401
Opossum, Development of.....	6, 16	Cooperation with California Institute of Technology.....	102
Oppenheimer, J. R., Publications by.....	84, 396, 397	Design of Instruments and Apparatus.....	101, 143
Optical Shop.....	143	Interferometer Measures on Ether Drift.....	114, 143
Optical Testing.....	141	Nebular Spectroscopy.....	109, 112, 126, 133
Ordway, Kathryn, Publication by.....	84	Observations with 20-Foot Interferometer.....	104, 110, 130
Organisation, Plan and Scope.....	ix	Photographic Observations of Moon.....	124
Organogenesis.....	4	Photographs of Nebulae.....	109, 125
Ornithorhynchus, Brain of.....	18	Publications by.....	84
Osborn, H. F.....	387	Pelagic Fish Eggs.....	282
Osborn, Wm. Church.....	v, xix	Pelagic Organisms, Examination of.....	283
Osborne, Thomas B., Death of.....	1	Pennsylvania, University of.....	213
Publications by.....	84, 91	Pentstemon, Studies in.....	179
Osgood, W. F.....	68	Pepper, George W.....	v
Publication by.....	84	Peromyscus, Studies on.....	346
Otosclerosis, Heredity of.....	62	Perrakis, Nicholas, Publications by.....	84
Ousdal, A. P.....	390	Solar Observations by.....	106, 123
Overton, J. B., Publication by.....	69	Pershing, John J.....	v, xix
Owen, D. E.....	338	Peters, R. A.....	379
Oxford, University of.....	150	Peters, W. J.....	vii
Oxidation with Potassium Permanganate.....	173	Data on Polar Regions.....	212
Oxygen, Atmospheric Absorption Bands of.....	120	Lecture by.....	245
Oxygen Consumption of Planaria.....	191	On Magnetic Disturbances.....	211
Ozonisation of Carotin.....	173	Publications by.....	84, 264, 265
Pacific International Committee on Oceanography.....	221	Revisions of Data from <i>Carnegie</i>	219
Pacific Science Congress, Fourth.....	245, 254, 256	Ship-Deviations.....	212
Packard, Earl H.....	388	Pettit, Edison.....	vi
Padilla, Ezequiel.....	299	Properties of Photoelectric Cells.....	140
Palaography, Report on.....	386	Publications by.....	86
Palaontology, Report on.....	387	Radiometric Investigations.....	104, 108, 109, 113, 121, 124, 125, 140
Paleobotany, Researches in.....	203, 205	Solar Spectrum.....	122
Pall, Gordan.....	361	Thermocouples and Thermopiles.....	114, 140, 142
Parallax, Determinations of Luminosity and.....	134	Philadelphia Physics Club.....	245
Parallaxes, Trigonometric.....	128	Phillips, Arthur W., Publication by.....	86
Parasites in Ovaries of Ant-Eater.....	25	Philosophy, Researches in.....	394
Park, E. A.....	371	Photoelectric Cells.....	140
Parker, David W.....	86	Photography, Solar.....	115
Parkinson, L. W.....	vii, 213	Photometry, Stellar.....	129
Parmelee, James.....	v, xix	Photosynthesis and Carbohydrate Chemistry.....	167
Atmospheric-Electric Program.....	225	Phylogeny of Climaxes.....	202
Parmenter, Haseltene Stedman, Publications by.....	73, 157	Physiology, Researches in.....	402
Parsons, Wm. Barclay.....	v, xix	Physics, Researches in.....	395
Parthenogenesis.....	42	Physical Constants.....	172
Partula, Variation of.....	336	Pickard, Greenleaf W.....	viii
Paton, Stewart.....	v, xix	Publications by.....	86, 265
Paul, J. H.....	vii	Radio Transmission.....	213
Magnetic Work on Board <i>Carnegie</i>	225, 226	Pickering, W. H.....	124, 401
Studies on Racial Metabolism.....	149	Piedras Negras Expedition, Report on.....	327
Pauli, W., Collaboration with Gregory Breit.....	215	Pierce, Cornelia M.....	85
Paper by.....	246	Pierce, Louise F.....	85
Pauling, Linus.....	348, 350	Pigeons, Endocrine Studies in.....	54
Publications by.....	76, 84, 89	Growth in.....	48
Paulin, Charles O.....	vi, 86	Race Differences in Thyroid Gland.....	58
Publications by.....	84, 89	Sex Differentials in.....	53
Peabody Museum Expeditions.....	330	Piggot, Charles S.....	vi
Pearson, Karl, Interferometer Measures on Ether Drift.....	114, 143	Publications by.....	77, 85, 79
Theory of Surfaces.....	415	Pike, Sidney R., Deceased.....	106
		Investigations in Solar Spectroscopy.....	106
		Pikes Peak.....	193
		Pincus, Gregory, Publication by.....	85
		Pine Ridge Reservation.....	360

	PAGE		PAGE
Pinkley, George.....	387	Reid, Harry Fielding.....	424
Pituitary Gland, Seasonal Changes in.....	55	Reinhart, Warren H., Publication by.....	87
Placental Sign, Nature of.....	25	Rennes, University of.....	163
Planaria Oxygen Consumption of.....	190	Research Council, International.....	107, 117
Plant Biology, Report of Division of.....	161	Respiratory Exchange, Helmet Apparatus for Studying.....	151
Laboratory for.....	8	Reygadas y Vertiz, Jose.....	299, 306
Podolsky, B.....	350	Rice, O. K.....	349
Pogo, Alexander.....	VIII, 359	Publications by.....	86
Polarities, Sun-Spot.....	117	Rich, A. R., Allergy in Tuberculosis.....	12
Polhemus, Irene.....	56	Publication by.....	86
Pollock, H. E. D., Archaeological Studies 299, 300, 310, 328		Rich, Willis.....	338
Pomona College Observatory.....	118	Richards, Theodore W., Atomic Weights... Publications by.....	351 86
Poole, Charles F.....	358	Richardson, Robert S., Publications by....	86, 107
Porpoise, Histological Studies of.....	27	Spectroheliograms.....	106, 116
Porter, Russell W., on Method of Optical Testing.....	114, 124, 141	Richmond, Myrtle L., Radiometric Observa- tions.....	105
Posnjak, E.....	VI	Richter, C. P., Publications by.....	87
Publications by.....	85, 78	Testicular Grafts.....	24
Post, Richard H.....	60, 64	Richter, M. N., Leukemia in Mice.....	35, 56
Publication by.....	34	Publication by.....	88
Potentilla, Experiments in.....	177	Ricketson, O. G. jr.....	VII, 10
Prairie Growth Studies.....	200, 201	Publication by.....	69
Praseodymium, Analysis of Complex Lines of	135	Uaxactun Project.....	299, 316
Pregl, F.....	177	Ricketson, Mrs. O. G. jr., Uaxactun Pro- ject.....	299, 316
Prescott, C. H. jr.....	340	Riddle, Oscar.....	VI, 7
Publication by.....	86	Metabolism of Pigeons.....	35, 53, 54, 58, 148, 152
Primate Placentation.....	26	Publications by.....	73, 87, 154
Primates, Ilium of Adult.....	79	Studies in Genes.....	7, 55, 56, 59
Prince, J. Dyneley.....	147	Rippy, J. Fred, Publications by.....	87
Pritchett, Henry S.....	V, XIX	Ritsman, E. G.....	153
Address on 25th Anniversary.....	58, 66	Metabolism of Sheep and Cows.....	148
Proper Motions.....	128	Publications by.....	87, 159
Psychology, Researches in.....	403	Roberts, H. S.....	VI
Psychometry, Standards in.....	63	Publications by.....	87, 79
Public Health Service, U. S.....	218	Robinson, True, Sunspot Areas and Posi- tions.....	105
Publications, List of.....	68, 70	Rockefeller Foundation of New York....	143, 149
Statistics of.....	66	Rockefeller Institute in New York.....	335
Pucher, George W.....	375	Rogers, Robert W., Publication by.....	87
Publications by.....	91	Rooney, W. J.....	VII
Pulse Rate of Embryonic Hearts.....	14	Earth-Resistivity.....	218, 239
Quartz Spectrograph.....	399	Terrestrial Electricity.....	216
Racial Metabolism.....	153	Publications by.....	87, 260
Racing Capacity.....	59, 60	Root, Elihu.....	V, X, XIX
Radcliffe College.....	359	Roscoe, M. H.....	380
Radial Velocities.....	131	Rose, Sylvia V. R.....	407
Radiation, Chemical Reactions by Molecules Activated by.....	349	Rosenwald, Julius.....	V, XIX
Radiation, Lunar.....	124	Ross, A. D.....	237, 252
Radiation from Mercury Arc.....	140	Ross, Frank E., Photographic Observations on Mount Wilson.....	106
Radio Engineers, Fourth Annual Conven- tion of Institute of.....	245, 251, 262, 263	Publications by.....	87
Radio Research Board of England.....	236	Ross, Llewellyn G.....	347
Radio Stations.....	222, 420	Rotifer, Male Production in.....	52
Radiometers, Development of.....	141	Roy, Arthur J.....	VI
Radiotelegraphy.....	245, 251, 262, 263	Royal Astrophysical Observatory.....	418
Radium Poisoning, Committee on.....	218	Roya, Ralph.....	381
Ramspurger, Hermann C.....	349	Ruger, Henry A.....	VIII
Publication by.....	86	Theory of Surfaces.....	415
Rare-Earths, Spectra of.....	136	Runyon, Ernest H., Germination of Coville's Seeds.....	187, 188
Rasetti, F.....	350	Ruppert, Karl.....	VII
Publication by.....	397	Archaeological Studies of, 299, 300, 301, 303, 310	
Ravitz, S. F.....	349		
Raymond, Harry.....	VI		
Reada, Chester A.....	387		
Rehani, Joseph F.....	302		

	PAGE		PAGE
Russell, G. Oscar, Physiological Cause of Voice Quality in Singing.....	402	Sherman, K. L., Terrestrial Electricity	216, 218, 239, 240, 264
Publication by.....	402	Publications by.....	88, 260, 261
Russell, Henry Norris.....	viii, 102, 401	Ship-Deviations caused by Rolling of Ship..	212
Composition on Sun's Atmosphere, 105, 108, 122		Shreve, Edith B., Transpiration Rates of Desert Perennials.....	186
Publications by.....	70, 83, 87, 398	Shreve, Forrest.....	vii
Ryerson, Martin A.....	v, xix	Desert Investigations.....	181, 184
Sanderson, K. C., Atmospheric-electric Observations.....	240	Publication by.....	88
Sanford, Roscoe F.....	vi	Shufeldt, E., Uaxactun Project.....	299, 316
Publications by.....	88, 111, 131	Shugrue, Mary Finn, Respiratory Quotient, 151, 152	
Spectroscopic Observations. 104, 111, 131, 132		Singing, American Teachers of.....	402
Sandground, J., Yucatan Medical Expedition.....	299, 301, 302	Skeletal Muscle Tonus.....	20
Sarton, George.....	viii	Sloth Anatomical Studies on.....	28
History of Science.....	359	Sloth, Placental Labyrinth of.....	25
Publications by.....	88	Smith, A. C.....	239
Satin, Sophie.....	vi	Smith, A. Ledyard, Archaeological Investigations.....	299, 316, 323, 325
Studies on Difference between Sexes... 40, 48		Smith, D. E.....	347
Schaffer, N. K., Publication by.....	80	Smith, G. Elliot.....	18
Schaller, J. F.....	vi	Smith, Gilbert M., Publication by.....	69
Publication by.....	81	Smith, Hampton.....	389
Schmidt, C. L. A.....	377	Smith, Helen M.....	99
Schieffelin, Barbara, Inter-racial Studies....	64	Smith, James H. C., Micro-Chemical Technique.....	170, 171, 172
Schmuck, Louise, Studies on <i>Sciara</i>	35, 48	Smith, Sinclair.....	vi, 102, 105
Schratz, Eduard, Water Balance of Desert Plants.....	164, 188	Publication by.....	88
Schultz, A. H., Publications by.....	69	Shielded-Vane Type Radiometer.....	141
Technique of Measuring Fetuses.....	32	Smith, Theobald.....	v
Schultz, Jock, Publication by.....	88	Smith, W. K., on Facial Vibrissæ of Opossum	20
Sciara, Studies on.....	48	Publication by.....	80
Scott, E. L.....	55	Smithsonian Institution, Bird Specimens for..	221
Scott, W. E.....	vii	Smithsonian Solar Observatory.....	232
Scripps Institution of Oceanography.....	230, 346	Snell, G. D., Publication by.....	89
Seal and Sea Lion, Myology and Osteology of	27	Société Scientifique d'Hygiène, etc.....	149
Seares, Frederick H.....	vi	Solar Activity, Terrestrial Magnetism and..	118, 211
Observations for Photovisual Magnitudes.....	104, 110, 129	Solar Research.....	115, 118, 119, 121
Publications by.....	88	Solberg, H.....	362, 364
Seashore, C. E.....	35	Publication by.....	89
Seashore, Paul T.....	201	Sommerfeld, A., Publications by, 89, 246, 396, 398	
Secular Variation.....	211	Soule, F. M.....	vii
Seismology.....	13	Oceanographic Work.....	225, 226
Report of Advisory Committee.....	415	Publication by.....	249
Seiwell, H. R., Biologist and Chemist on Carnegie.....	230	Spectra, Neon Lamps for Comparison.....	140
Lecture at Brown University.....	245	Spectra Scattered by Molecules.....	349
Oceanographic Work of.....	225	Spectra of Rare-Earths.....	136
Publications by.....	88, 266, 267	Spectra of Stars.....	132, 134
Senior, H. D., Publication by.....	88	Spectroheliograph, Research with.....	118
Sequoia National Park.....	204	Spectroscopy, Studies.....	126, 130
Sereque, Arthur F., Publications by.....	75, 155	Spectrophotometry of Solar Lines.....	121
Sex Studies.....	48, 51, 56, 61	Stellar Lines.....	134
Sexes, Difference between.....	48, 53	Spectrum of Hafnium.....	137
Shackleton South Pole Expedition.....	338	Spoehr, H. A.....	vii, 8
Shane, C. D., Solar Spectroscopic Observations.....	106	Publications by.....	78
Shapley, H. P., Trigonometric Parallaxes and Period-Luminosity Relationship.....	135	Report as Chairman Division of Plant Biology.....	161
Shattuck, G. C., Yucatan Medical Expedition.....	301	Spoerl, Elsie.....	394
Shenstone, A. G., Publication by.....	395	Spohn, A. J.....	378
Shepherd, E. S.....	vi	Spooner, John C.....	v, x
Sherman, H. C.....	viii, 378	Standards, Laboratory, Bureau of.....	213
Amylases and Related Enzymes.....	351	Stanford University.....	161
		Stanton, W. Layton.....	389
		Stars, Spectra of.....	132, 134
		Luminosity Distribution of M-Type....	136
		Steggerda, Morris, Publications by....	69, 89, 155
		Stehn, C. E.....	70

	PAGE		PAGE
Steinour, H. H.	348	Teeple, John E.	331
Publication by	84	Maya Hieroglyphic Writing	330
Stellar Investigations	98, 128, 129, 130, 134	Temple of the Warriors	10, 299
Sternberg, Elisabeth, Publication by	84	Tennent, D. H.	vii, viii
Sun-Spot Polarities	105	Studies on Echinometra	277, 297, 347
Stetson, Harlan T.	213	Terrestrial Magnetism	118, 149
Stevens, Samuel N.	403	Report of Department of	209
St. John, Charles E.	vi	Tharp, B. C., Coastal Prairie and Desert Plains	200, 201
Publications by	89, 121	Thayer, William S.	v, xix
Solar Physics Committee of Inter- national Astronomical Union	106, 117	Thermal Clone, Genetics of	42
Solar Researches of	104, 108, 118, 121	Thomassen, L., Publications by	90, 397
Stock, Chester	viii, 388, 391	Thomson, Andrew, Director Apia Observa- tory	240
Palentological Investigations	390	Publications by	90, 267
Publications by	89, 391	Thomson, Elihu	102
Stock, Leo F.	vi, 86	Thorndike, E. L.	35
Publications by	89, 88	Tichanowsky, J. J.	268
Storey, William B.	v, xix	Tinklepaugh, O. L.	24
Stoyanow, A. A., Palæozoic Invertebrate Fossil Material	392	Tolman, Richard C.	349, 350
Strain, Harold H.	vii	Publications by	86, 90, 396, 397, 398
Studies in Plant Biology	167, 168, 170, 171, 174, 175	Tonus, Skeletal Muscle	20
Straus, W. L. jr., on Foot Musculature	30, 31	Torreson, O. W.	vii
Publications by	89	Magnetic Work on Board <i>Carnegie</i>	225
Studies on Ilium	29	Studies on Racial Metabolism	149
Streeter, George L.	vi, 35	Tortugas Laboratory, Report of Investiga- tions at	277
Publications by	68, 89	Tower, S. S., On Skeletal Muscle Tonus	19, 20
Report of Department of Embryology	3	Publication by	90
Strieck, F., Metabolism during Muscular Work	149, 152	Transplant Experiments	176
Stromberg, Gustaf	vi	Trees, Gases in Trunks of	166
Publications by	89, 111, 131	Trees, Growth in	165
Stellar Spectroscopic Observations	104, 112, 131, 136	Tramatodes, Studies on Marine	290
Sturdivant, J. H., Publications by	84, 89	Tuberculosis, Allergy in	12
Sturtevant, A. H., Germinal Material in Relation to Heredity	338, 348	Tucson, Desert Sanatorium at	242
Publication by	69	Tucson Magnetic Observatory	220, 242
Sumner, E. L. jr.	346	Tufts College	213
Sumner, F. B.	viii	Tulane University Expeditions	330
Publications by	90	Tumor-Cells, Studies on	12
Studies with <i>Peromyscus</i>	346	Tunnell, G.	vi
Sun, Identification of Boron in	123	Publications by	85, 79
Sun, Ultra-Violet Energy Curve of	122	Turbulence, Problem of	365
Sun's Atmosphere, Composition of	122	Turner, Abby H., Racial Metabolism	154
Sun-spot Activity	116	Tuve, M. A.	vii
Sun-spot Polarities	117	Cooperation in Cosmical Sciences	244
Sutton, Richard M., Publications by	90, 396, 397	Lectures by	245, 268
Sverdrup, H. U.	viii	Publications by	74, 78, 245, 250, 262, 263, 267, 268
Magnetic, Electric and Oceanographic Programs	212, 245	Work in Atomic Physics	214
Publications by	90, 267	Ure, W., Publication by	90
Swanson, J. C.	213	Uxactun, Excavations at	10, 299, 316, 325
Swingle, Walter T.	181	Ullian, Silka S., Publication by	83
Sykes, Godfrey	vii, 164	Ultra-Violet Solar Radiation	121, 132
Meteorological Investigations	184	Unsold, Albrecht, Interpretation of Line Contours	106, 108, 122
Observations on Delta of Colorado River	185	Publications by	90
Syntognath Habits and Development, Report on	279	Vacuum Tubes, High-Current Discharges in	138
Taft, William H.	v	Valley of Ten Thousand Smokes	72
<i>Tananger</i> Expedition	228	<i>Valonia ventricosa</i>	277
Tange, Masaharu, Publication by	87	van Maanen, Adrian	vi
Taxonomy, Experimental	175, 355	Measurements of Proper Motions	104, 109, 110, 127, 128
Taylor, A. H.	213	Measurements of Trigonometric Paral- laxes	136
Taylor, W. R.	338	Publications by	91
		Vascular System	34

	PAGE		PAGE
Vassar College, Physical Laboratory of....	118	White, Harvey E., Lines of Ionised Praseodymium.....	106, 112, 127
Varnum, W. B.....	vi	White, Henry.....	v
Vaughan, T. Wayland.....	256	White, Joseph D., Publication by.....	89
Vestal, A. G., on Grassland Climax.....	200, 201	White, Walter P.....	vi
Vegetation of Desert Laboratory.....	182	Whitfield, C. J., Experimental Adaptation and Morphogeny.....	196
Vibrissae, Cortical Localisation of Movements of Facial.....	20	Whitney, D. D., Publication by.....	91
Vickery, H. B.....	viii, 1	Sex Control in Rotifers.....	35, 52
On Vegetable Proteins.....	367	Whorf, B. L., Translations of Nahuatl Manuscripts.....	231
Publications by.....	88, 91	Wickersham, George W.....	v, xix
Virus Studies.....	13	Wieland, G. R.....	vii
Volar Pads in Human Embryo.....	8	Publications by.....	91
Volcanological Studies in Java and Bali....	69	Researches in Paleobotany.....	205
Wait, G. R.....	vii	Williams, George D., Publications by.....	91, 155
Atmospheric-Electricity.....	216, 217, 219	Williams, R. R.....	viii, 379, 380, 381, 383
Deviations Caused by Rolling of Ship..	212	Physiological Functions of Vitamins...	377
On Cause of Fog-Formation.....	218	Willis, Bailey.....	viii, 15, 424
Publications by, 91, 268, 269, 270, 271, 272, 273, 274, 275		Publication by.....	68
Revision of Data and Compilations,...	219, 240, 243	Wilson, E. A., Publications edited by.....	154
Terrestrial Electricity.....	216	Wilson, J. T.....	18
Tests of Apparatus and Improvements....	240	Wilson, R. E.....	vi
Walcott, Charles D.....	v, x	Space Velocities of Stars.....	95
Walcott, Henry P.....	v, x	Wilson, W.....	213
Wallis, W. F.....	vii, 240	Winger, Ralph E., Publications by.....	91, 398
Publications by.....	275, 276	Winkenwerder, W. L., Permeability of Epithelium of Gall-Bladder.....	31
Walter, A., Meteorological Service.....	231	Publication by.....	98
Ware, Louise, Intensities of Solar and Stellar Spectral Lines.....	105	Wislocki, G. B., Histological Studies of Porpoise.....	27
Publications by.....	89, 121	Parasites in Ovaries of Ant-Eater.....	25
Warner, A. H., Publications by.....	91, 396, 398	Placentation Studies.....	25, 26, 28
Wartmann, William.....	vii	Publications by.....	68, 87, 98
Studies on Echinometra.....	277	Testicular Grafts.....	24
Washington, H. S.....	vi	Wissler, Clark.....	viii, 35
Publications by.....	91, 78, 80	Wolbach, S. B.....	385
Waterfall, K. F., Publication by.....	91	Woldstedt, Paul.....	387
Water Content of Covillea Leaves.....	188	Wood, F. W.....	viii, 237
Waterman, R. E.....	379, 380, 381	Wood, H. O.....	viii
Watheroo Magnetic Observatory, 210, 216, 218, 234, 243		Seismological Studies of.....	417, 419
Watson-Watt, R. A.....	236	Wood, R. W.....	395
Wave-Lengths, Stellar.....	98	Publications by.....	18, 258, 263
Weather Bureau, Meteorological Observations for use of.....	115	Wood, Thelma, Publication by.....	98
Weaver, J. E.....	viii	Researches on <i>Cladocera</i>	35
Publications by.....	69, 91	Researches on <i>Daphnia longispina</i>	43, 44
True Prairie and Subolimax Prairie....	200	Woodburn, Janet.....	86
Webb, Alice Leman, Mental Tests.....	64	Woodward, Robert S.....	v
Weed, L. H.....	viii	Woodring, Wendell P., Publication by....	68
Publications by.....	91	Wright, Carroll D.....	v, x
On Monro-Kellie Hypothesis.....	21	Wright, F. E.....	400, 401
Welch, William H.....	v, xix	Gravity-Survey on U. S. Submarine S-21	72, 219
Wellman, H. B.....	348	Observations of Moon.....	106, 124
Wenner, R. R.....	349	Publication by.....	80
West China Union University.....	149	Würzburg, University of.....	149, 152
Western Australia, University of.....	237	X-rays on Non-Disjunction of X-Chromosomes.....	45
Westland, C. J., Publication by.....	80	Yale Medical Society.....	149
Solar Observations by.....	240, 241, 242	Yale University.....	369
Weyl, H.....	215, 246	Yamanouchi, Shigeo.....	vii
Wheatstone Laboratory.....	214	Life Histories and Cytology of Marine Algae.....	277, 297
White, Andrew D.....	x	Yensen, T. D., Publications by.....	98, 396
White, David.....	viii	Yerkes Observatory.....	117, 118
Fossil Floras in Grand Canyon.....	392	Yerkes, Ada W., Publication by.....	88
White, Edward D.....	v		

	PAGE		PAGE
Yerkes, Robert M.....	18	Zachariasen, W.....	348
Publication by.....	98	Zies, E. G.....	vi, 4
Yosemite National Park.....	204	Publications by.....	98, 78, 82
Yost, Don M., Publications by.....	91, 398	Volcanological Studies in Java and Bali.....	69
Young, W. G., Carotin from Sun-Flowers..	172	Zeiss, C., Microscopic Study of Metallurgy.....	208
Yusatan Medical Expedition.....	299	Zwicky, F., Publications by...76, 92, 396, 397, 398	

